Aeromodelling

R. H. WARRING

AEROMODELLING

R. H. WARRING
Author of *Radio-Controlled Models*, etc.

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CHAPTER I

MODEL AIRCRAFT DEFINED AND CLASSIFIED

THE general description "model aircraft" embraces a whole variety of different types, with a very wide range of interest and appeal both as regards age and intelligence level. Thus many of the more elementary types of model aircraft, some of which may only cost a shilling or so, are properly classified as "toys" and are specifically intended to appeal as such. At the other end of the scale there are model aircraft built with maximum performance in mind, and conforming to particular specifications, as a world-wide hobby-sport; and radio-controlled models which may cost up to £30 to £35 to build and in addition carry electronic equipment itself costing a further £100 or more. Their appeal is essentially adult, although many classes of contest-type models are basically inexpensive, placing a premium on individual skill, and appealing to all types of enthusiasts from the middle teenage upwards.

The first main broad sub-division of model aircraft types is into *flying* and *non-flying* models. The latter are invariably scale models, ranging from simple assemblies of carved or moulded components (e.g. plastic kits) to fully detailed and highly elaborate models following similar "skeleton" or framework details as the full-size prototype. Primarily they satisfy a *collector's* instinct and cover a quite distinct branch of aeromodelling.

The purpose of this book is to cover *flying models*, and here again we can immediately split this main group into *free-flight models* and *control-line models*. The former covers all models capable of flying freely through the air in a similar manner to a full-size aircraft. Control-line models, on the other hand, are restrained in their flight path by being attached to lines (usually two but sometimes a single line), and so must fly in circles. Actually their flight path is not as limited as might appear at

first sight since one of the basic features of a control-line model is that the operator actually controls elevator movement during flight, permitting a wide range of manœuvres to be carried out.

Free-flight models have the greater appeal as *flying* models, but require fairly large areas of open ground from which they can be flown. Control-line models can be operated in relatively small areas and also place far less premium on design and trimming skill, since they are flown under control. They are also less affected by winds for the same reason, and generally are

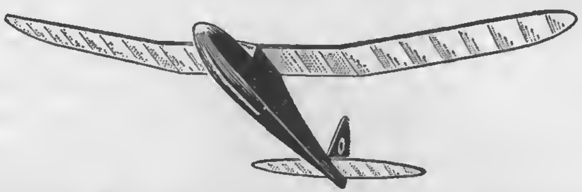


FIG. 1. Semi-scale glider layout features a clean and generally "realistic" appearance, although in this case a polyhedral wing is employed.

more robustly constructed in any case since weight is not such a critical factor. The two basic forms—free-flight and control-line—thus have quite different appeals. It is unusual to find an established modeller enthusiastic about both. He usually concentrates on one type of flying or the other—and generally specializes in a particular *type*. There are so many different types to choose from that no one person can hope to become expert with each, although a lot of useful experience and knowledge can be gained in trying different types initially to find the one which offers the most satisfaction or interest.

Free-flight models can be grouped according to their motive power, as—

(i) Gliders—which have no motive power (but many gliders are convertible to auxiliary power by the fitting of a small pylon-mounted engine).

(ii) Rubber models—where the power to drive the propeller is supplied by the unwinding of a rubber motor (never "elastic" —that is purely for toys, and many rubber models are far from being toys!).

(iii) Power models—where the power unit is a miniature internal combustion engine.

(iv) Jets—where the power unit is a miniature jet engine (in practice, confined to standard sizes of a small proprietary rocket unit called "Jetex").

Each of these groups may embrace three distinct types, referring basically to overall shape and appearance. These are, *original* designs where shapes and proportions are derived solely on the basis of achieving maximum performance; *scale models*; and *semi-scale* models. Original models, especially those designed

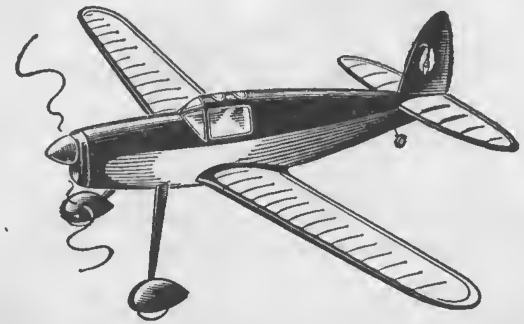


FIG. 2. A low wing semi-scale rubber-powered model. Although "realistic" in appearance it is a tricky model to design and fly.

for contest flying, generally look quite unlike full-size aeroplanes, and are often criticized in this respect. There are many good reasons why they should have such unusual shapes or layouts, however, all connected with stability and efficiency.

A full-size aeroplane is flown under the control of the pilot, who can correct any deviation from a proper flight path caused by gusts, etc. A similar form of "control" has to be achieved automatically with a free-flight model—and since a model is so much smaller and lighter it is more readily upset in any case. Thus a successful free-flight model has to have a large reserve of built-in or inherent stability, which can be achieved by such methods as increasing the upward inclination of the wing tips or dihedral (and in some cases producing the required dihedral in two stages by cranking the wing); increasing tailplane and fin areas; using a fairly long fuselage to increase the moment arm between wing and tail; mounting the wing above the fuselage on a pylon; and so on.

From the efficiency point of view, wing sections are usually made thinner and undercambered; fuselages are reduced in section to save drag and weight; and, in the case of rubber models in particular, a larger diameter propeller is used. Thus between the demands of stability and efficiency the resulting design bears little or no resemblance to a full-size aeroplane

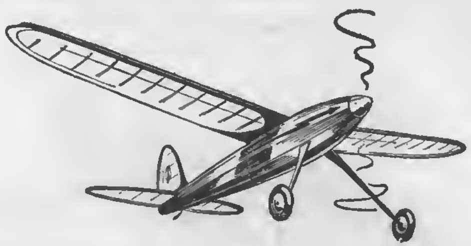


FIG. 3. This is a functional rubber-powered model which still maintains something of the general appearance of a full-size aeroplane. A "stilty" undercarriage is inescapable with a rubber-powered model.

and the more specialized a contest design it is the greater may be this difference. It is, in fact, no longer a *model* aeroplane but a small-size aeroplane designed to fly without a pilot and to give the best possible performance within the limitations set by its size and type. In other words, it is really a "full-size" pilotless aeroplane!

Conversely, since the original design needs so much departure from an orthodox full-size aeroplane layout, it is to be expected that the *scale model* which duplicates a full-size outline will not make a good free-flight model. This, as a generalization, is true. However, certain full-size layouts have a reasonable margin of stability to start with (notably high-wing monoplanes), and can make suitable flying scale models with some further modifications—generally an increase in wing dihedral and tail surface areas. Although they may be made reasonably stable in flight by this (or other) means they will still not have anything like the *performance* of an original design. Even to approach a similar standard of performance certain design features must be so exaggerated that the model no longer approximates to anything like near scale.

This leads to the third basic type—the *semi-scale model*. Here

the designer aims, basically, to produce an original layout with good stability and performance and then add "realism" to the shape, such as by incorporating a cabin in the fuselage shape and generally aiming for attractive or "realistic" wing shapes

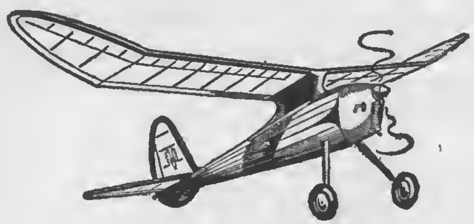


FIG. 4. Typical of the older pylon layout which originated about 1940 for power duration models. Modern pylon models are even more functional with thinner, stick-type fuselages.

and proportions, etc. The greater the "realism" introduced, in general, the greater the penalty as regards both stability and performance. No such model can hope to have a contest-type performance, yet at the same time it will be safer to fly, and fly much better, than a scale model.

As far as free-flight models are concerned, therefore, it is impossible to have it both ways. The high-performance original

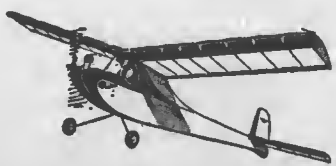


FIG. 5. This layout is a compromise between "performance" and "looks" in a free-flight power model—retaining a pylon-type wing mount but turning it into a cabin.

design cannot be made to look "realistic"; whilst the wider appeal of the realistic scale model is offset by its poorer flying performance and its greater liability to crash and damage itself.

Basically, therefore, it is necessary to decide which type of flying you want. If you want good flying performance, then an original design is the logical choice; although a semi-scale model may be more attractive if you are only flying for fun

rather than aiming for "contest" performance. Should a scale model be the choice, then it can only be emphasized that previous experience with original or semi-scale models will be invaluable in tackling the trickier trimming problems involved. The majority of flying model enthusiasts make the basic mistake of starting out with a scale design as their first model, because the realism appeals to them, when they are likely to achieve only disappointment and an early end to the model. This applies particularly to the smaller sizes of models. Larger

FIG. 6. The unusual layout is popular for power sports models, but unsuited for high-performance contest flying.

scale models of a suitable prototype are generally easier to trim, particularly in the case of power models.

Control-line models are invariably engine-powered. No rubber motor or "Jetex" unit would give a long enough flight, although pulse-jets may be used on control-line models (see Chapter 12). Stability requirements are reduced to a minimum, so in this case scale models are just as suitable as original designs for normal flying. However, to extend the scope of control-line flying—e.g. to make the model fully aerobatic (within the limits of the model being tethered), or for maximum speed performance, again original design features are introduced. These considerations lead to the following types of control-line models—

(i) Sports models—which may be scale, semi-scale, or original in layout and have limited aerobatic performance. Original designs with a reasonable aerobatic performance are also called "trainers."

(ii) Stunt models—which are essentially original designs evolved to provide maximum manœuvrability.

(iii) Combat models—which are really stunt models designed

to provide even more rapid response to control movement and are intended to be flown two or more in the same circuit by independent pilots in "combat."

(iv) Team Racers—which are essentially semi-scale models on the lines of full-size lightplane racers for racing two or more in the same circuit over a specified distance (number of laps).

(v) Speed models—which are designed for out-and-out speed performance and are classified by engine size.

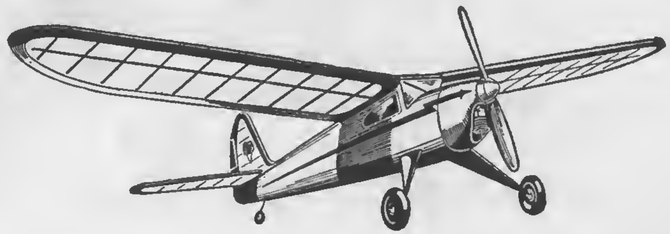


FIG. 7. The typical "sports type" free-flight power model has a cabin and "realistic" outlines and proportions.

Scale models are sometimes classified separately, although they are essentially "sports" type models and seldom have a fully aerobatic performance.

Both plans and kits of all types of free-flight and control-line models are readily available. Until a certain amount of practical experience has been obtained with a particular type of model it is generally best to build from a kit, particularly as the modern kit usually contains a proportion of prefabricated parts (e.g. die-cut sheet parts) which make for greater accuracy in assembly. Instructions are usually specific both as regards assembly and trimming for flight. The more experienced builder may prefer to work from *plans* and basic materials, choosing published designs of particular appeal or proven performance. Not until the modeller is experienced both in *construction* of and *flying* a particular type should he attempt to design his own models.

The "traditional" method of achieving the best possible results with free-flight models was to start with gliders, progress to rubber models and thence to power models. This no longer holds true as with good kits available, satisfactory results may

be obtained by starting with a semi-scale power model. Trimming and flying technique, however, is something which can only be mastered with practice, and there are no short cuts in this respect other than choosing a good basic design to start with. This is a model with a good reserve of inherent stability and a tolerance to being mis-handled, rather than aiming

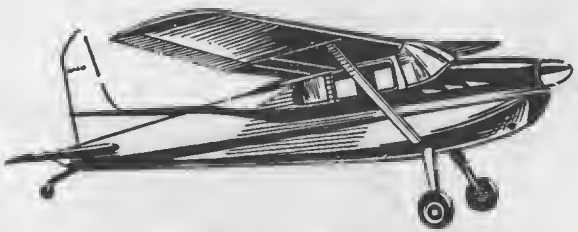


FIG. 8. For free-flight scale models a high-wing design makes the best prototype.

straight away for a model which has maximum performance, or high degree of scale realism.

With control-line models, success is even more a matter of practical flying experience, starting with a "trainer" to master the rudiments of controlling the model in circling flight and then advancing to a more specialized design.

Time spent in building and flying a "trainer" type of model in any category is never wasted, when starting aeromodelling, as success is only built on experience. Basically, in fact, the hobby of both building *and* flying model aircraft is essentially a practical one, and a real knowledge and appreciation of the problems involved starts only when the first model is completed.

CHAPTER 2

TOOLS AND MATERIALS

A PARTICULAR virtue of model aircraft construction is that it requires only a minimum of tools and equipment. The one essential feature for a "workshop" is a flat and true *building board* at least as large as the longest single component of the model under construction. A large drawing board is excellent for this, but unnecessarily expensive if purchased new. Any similar board will do—or a softwood kitchen table top—provided it is flat and true, and is soft enough for pins to be stuck into it. The building board *must* be true and smooth-surfaced, for flat frames are built directly on it and their accuracy depends on the board surface being true. It should be kept only for model building.

Also required is a working surface on which the board can be rested. This should be at least three feet long so that standard lengths of sheet balsa can be cut on it. Alternatively, the building board itself can be used as a base for stripping and cutting wood where the working surface is a piece of domestic furniture which must not be damaged. It is a little difficult to use a building board for both purposes, however, once a plan has been laid on it and building has commenced.

A basic set of tools boils down to a modelling knife with spare blades, some razor blades, a razor saw, a steel rule, a hand drill, square- and round-nose pliers, and a fretsaw. Other tools will be found useful, but not necessarily essential (Table I).

The modelling knife is used for most of the cutting jobs in sheet and strip balsa, and can also be used for carving with a different blade. Typical blade shapes and their purposes are shown in Fig. 9. These represent only a proportion of the blade shapes available, but the others are more suited to wood carving jobs rather than model aircraft construction.

The modelling knife can be used for cutting strip balsa to

TABLE I. AEROMODELLING TOOLS

Tool	Use(s)
Modelling knife.	Cutting balsa sheet and small strip sections, carving and shaping.
Razor blades.	Cutting thin balsa sheet and strip, trimming tissue covering.
Razor saw.	Cutting larger strip sizes.
Stiffback saw.	Cutting balsa block.
Fretsaw.	Cutting thicker balsa sheet to curved outlines, cutting ply.
Coping saw.	Cutting thick sheet balsa and block to curved outlines.
Hand drill.	All drilling jobs; also, fitted with a hook, for winding up rubber motors.
Square-nose pliers.	Making "square" bends in wire, holding nuts when tightening, etc.
Round-nose pliers.	Bending wire loops, etc.
Vice.	Bending heavier gauge wire, holding parts for drilling, etc.
Soldering iron.	Soldering wire parts together. (*Note:* for radio-control model installations, an electric soldering iron is essential.)
Small clamps.	Useful for certain assembly jobs, but most clamping requirements can be met with pins.
Small screw-drivers.	For nut and bolt assemblies (e.g. mounting engines).
Steel rule.	Measuring and also as guide for cutting straight lines with a modelling knife.
Sanding block.	For all sandpapering jobs, although a piece of thick balsa sheet will usually be suitable instead of a special sanding block.
Hacksaw (small).	Metal cutting; also useful for cutting off engine mounting bolts, etc., and thicker gauge wire.
Wire cutters.	For cutting steel wire up to 16 s.w.g.
Files.	For cutting engine mounting bolts or steel wire thicker than 16 s.w.g.; also for balancing plastic propellers.
Hand spray.	Invaluable for water-spraying tissue covering.
Spraygun.	The best method of applying dopes and finishes, but brushes can be used instead.

length in all sizes up to about 3/16 in. square. For larger sizes, and particularly in denser wood, the knife blade tends to crush the wood and it is difficult to produce an accurate cut, so a

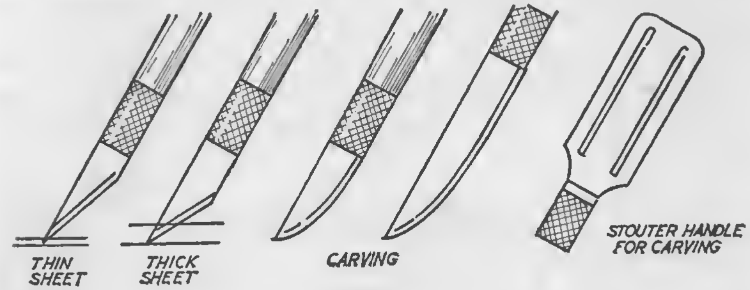


Fig. 9

razor saw is a better tool (Fig. 10). This can also be used for accurate straight cutting of thicker sheet balsa and block.

A razor blade can also be used instead of a modelling knife for sheet and strip balsa. It is not so accurate for cutting thicker sheet, but is generally more accurate than a knife for cutting 1/32 and 1/16 in. thick sheet. Razor blades, in fact, used to be

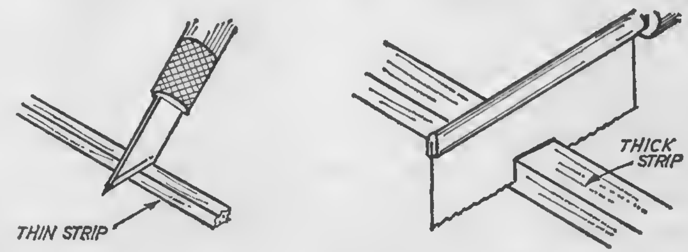


Fig. 10

the main cutting tool for aeromodelling work before modelling knives were introduced. Today, however, they are mainly reserved for lighter cutting work, and for trimming off surplus material after tissue covering.

For cutting such plywood parts as may be used a fretsaw is necessary, although a razor saw or small hacksaw can be used for straight cuts. A fretsaw or coping saw is also the best tool for curved cuts in thick sheet balsa (e.g. ¼ in. thick or more).

Pliers are used for wire bending and cutting (although wire thicker than 16 s.w.g. is best cut with a small triangular file). Small flat-nose pliers are also extremely useful for inserting and withdrawing pins used to hold parts in place during cementing up. Pins themselves are an indispensable part of model building. Some people prefer glass-headed modelling pins with hardened shanks, others use ordinary domestic pins. Whichever type you choose, buy by the gross in order to be sure that you always have enough.

TABLE II. BALSA GRADES

Grade	Ultra-Light	Light	Medium-Soft	Medium	Hard (or Heavy)	Extra-Hard
Density lb./cu.ft.	under 6	6–7	7–9	9–12	12–16	over 16

The standard material for model aircraft construction is *Balsa.* This is a tropical wood found only in South America and which, due largely to its rapid rate of growth, is very much lighter than any other wood. At the same time it varies widely in density from tree to tree, or even in the same log. It is usually graded according to density or weight per cubic foot (Table II), strength being more or less proportional to density. Thus hard (heavier) balsa is used for parts which need the greatest strength (such as wing spars) and softer (lighter) wood for parts where weight is to be saved. Plans often specify which grade of balsa is to be used for particular parts, otherwise modellers choose the grade according to their individual preferences. Failing such experience, Table IV can be used as a guide.

The actual properties of a length of balsa (particularly balsa sheet) will also depend on the "cut." If the sheet is cut from a log tangentially to the annular rings it will be fairly "bendable" in an edge to edge direction. Sheet cut from the log in line with the medullary rays, on the other hand, will be much stiffer

TABLE III. TYPICAL WEIGHTS OF SHEET BALSA
(weight in ounces for 36×3 in. sheet)

Thickness	$\frac{1}{32}$ in.	$\frac{1}{16}$ in.	$\frac{3}{32}$ in.	$\frac{1}{8}$ in.	$\frac{3}{16}$ in.	$\frac{1}{4}$ in.	$\frac{3}{8}$ in.	$\frac{1}{2}$ in.
Ultra-light	less than $\frac{3}{16}$	less than $\frac{3}{8}$	less than $\frac{9}{16}$	less than $\frac{3}{4}$	less than $1\frac{1}{8}$	less than $1\frac{1}{2}$	less than $2\frac{1}{4}$	less than 3
Light	$\frac{3}{16}$	$\frac{3}{8}$	$\frac{9}{16}$	$\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{1}{2}$	$2\frac{1}{4}$	3
Medium (typical)	$\frac{3}{8}$	$\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{1}{2}$	$2\frac{1}{4}$	3	$4\frac{1}{2}$	6
Hard	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	3	4	6	8
Extra-hard	over $\frac{1}{2}$	over 1	over $1\frac{1}{2}$	over 2	over 3	over 4	over 6	over 8

TABLE IV. TYPICAL BALSA SELECTION

Component	Grade	Cut
Fuselage: Longerons	Medium or Hard	Straight grain
Spacers	Medium or Medium-Soft	Random
Sheeting	Medium-Soft	Random
Wings: Leading edge	Light	Random
Spars	Hard	Straight
Trailing edge	Medium	Quarter grain
Ribs	Light	Quarter grain
Sheeting	Light	Straight grain
Tailplane: Spars	Medium-Soft	Quarter grain
Ribs	Light	Quarter grain
Solid Block Tips	Ultra-Light	Random
Sheet Balsa:		
Wings	Light	Quarter grain
Tailplanes	Light	Quarter grain
Fins	Light	Quarter grain

and tend to split if bent. This is normally termed "quarter-grain" stock and can be identified by the speckled appearance of the surface grain. Quarter-grain balsa is the logical choice for parts which have to be stiff and rigid, such as wing ribs and sheet tailplane surfaces. Tangent-cut sheet is the logical choice

for curved components, such as sheet covering for wing leading edges.

The basic "cuts" are illustrated in Fig. 11, whilst Table IV gives their typical applications. The experienced modeller often goes to a lot of trouble to sort out the right "cut" as well as "grade" of balsa for a particular model. The less experienced modeller can receive guidance from the local model shop where he buys his stock materials. In the case of kits, "grade" and

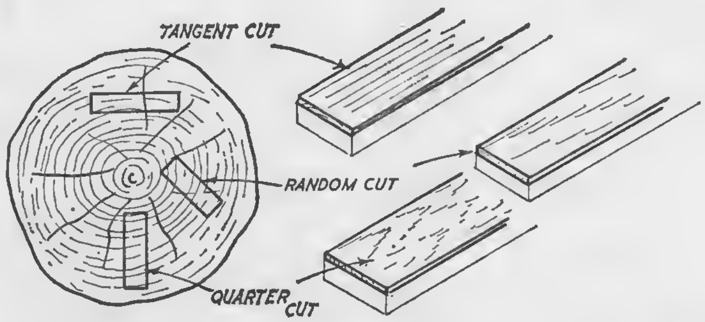


FIG. 11

"cut" selection is done by the kit manufacturer, but is by no means as complete as can be done by individual selection. In some cases, too, choice of grade is influenced more by pre-fabrication requirements than anything else. The good kit design, however, allows for this and other possible variations. The experienced modeller building from a kit may, however, prefer to replace certain parts—particularly wing spars, wing tip blocks which may not be equal weight, wing sheeting which is too heavy or too rigid, etc.

Other woods used for model aircraft construction are obeche, spruce, hardwoods such as ash and beech, and plywood. Obeche has relatively little application, being as heavy as spruce and harder, but more brittle. It was used as a substitute for balsa when that material was in short supply during World War II and has survived as a generally modelling wood (particularly for boats). Today it has little or no application for model aircraft construction. Spruce has a particular application for spars in larger model gliders where wing sections are

thin and a small section spar has to be used. It is roughly three times as heavy as medium-grade balsa, but very much stronger. It may also be used for other highly stressed members in other built-up structures on larger models, e.g. longerons. The hardwoods, such as beech, ash, etc., are used exclusively for motor bearers on power models, and for other "strong" points such as undercarriage mounting points on radio-control models where the main undercarriage may be attached to the wings.

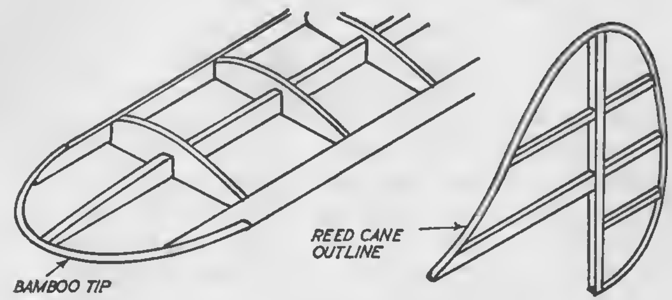


FIG. 12

Plywood is used for main fuselage formers, such as the front former or firewall on power models which carries both the motor bearers and undercarriage fixing. It is also used for local reinforcement, such as spar braces at wing dihedral joints, etc. Thin ply, fretted out, may also be used for wing ribs on Continental model designs where balsa may be comparatively scarce, but ply is not normally regarded as a substitute for balsa sheet, only as a material with specific applications.

The best plywood for model aircraft use is aircraft quality beech ply, which is available in thicknesses from 0·5 mm. upwards. Ordinary "domestic" plywood, or marine ply (which is a mahogany ply), is not generally suitable or available in the thinner thicknesses. All plywood thicknesses are specified in millimetres (except in the U.S.A. and Canada) although commonly spoken of in terms of nominal inch thickness in this country (Table V).

Limited use is also made of other wood-like materials, such as bamboo and reed cane (Fig. 12). Both are materials which

can be readily bent to curved shapes for wing-tip outlines, etc. by gentle heating in the case of bamboo, or simply bending in the case of the flexible reed canes. Bamboo, being a rigid, strong material, is also used for rear pegs on rubber motors (anchoring the rear end of the rubber motor) and is much better than a hardwood dowel in this respect; and for rubber model undercarriage legs.

TABLE V. PLYWOOD THICKNESSES

Nominal Thickness	Approx. Equivalent
0·5 mm.	—
0·8 mm.	$\frac{1}{32}$ in.
1 mm.	$\frac{3}{64}$ in.
1·5 mm.	$\frac{1}{16}$ in.
2 mm.	$\frac{5}{64}$ in.
2·9 mm.	$\frac{3}{32}$ in.
3 mm.	$\frac{1}{8}$ in.
4 mm.	$\frac{5}{32}$ in.
5 mm.	$\frac{13}{64}$ in.
6 mm.	$\frac{1}{4}$ in.

Sheet plastic materials have very limited application, except for "transparencies" and mouldings. The material normally used is acetate sheet for "glazing" cabin windows on scale or semi-scale models; or moulded to form cockpit canopies, etc. Mouldings in thicker acetate sheet may also be used for cowlings, etc. Thin "Perspex" sheet may also be used for larger cockpit canopy mouldings, etc., but acetate is the normal choice. Kits normally include finished mouldings of this type (which merely need trimming to fit); and may also include cowling mouldings and similar detail parts. Ready-to-fly models are also produced from polystyrene sheet mouldings, this material being more dimensionally stable than acetate. It is not, however, normally used for home-made mouldings.

The only other plastic material used to any extent in flying

model construction is a comparatively new material—expanded polystyrene. This, basically, is a "foamed" plastic which can be expanded in a mould to a required shape, or into slab form for subsequent cutting to shape. Material density may range from as low as 3 pounds per cubic foot up to 10 pounds per cubic foot, a typical density for general purpose mouldings being about 4 pounds per cubic foot. It is thus lighter than balsa but, unless produced in the form of shell mouldings, must be shaped "from the solid." Thus an expanded polystyrene component such as a wing is not necessarily lighter than a built-up balsa wing.

Kit models based on expanded polystyrene construction invariably supply the parts involved as finished mouldings. The strength of such mouldings may be enhanced by a process of remelting and pressing the surface to form a toughened skin (usually a part of the moulding process). Home-made expanded polystyrene parts can be cut from solid with a heated wire, the material being too soft and crumbly to saw or carve in the usual way. "Skin-toughening" can then be achieved by covering with tissue or, in the case of larger components such as wings, covering with sheet balsa. The latter technique provides a rapid method of making large wings for radio-control models.

Both the making and finishing of expanded polystyrene parts require special techniques, such as special adhesives and fillers, and also protection of the surface against model engine fuels when used for power model construction. Normal cellulose dopes and finishes cannot be used on polystyrene as these will dissolve the material.

Glass fibre mouldings are also used to a limited extent for larger models. The main disadvantage is that glass fibre mouldings are relatively heavy, compared with balsa construction for example, and thus only offer advantages in larger size thin shell mouldings where the high strength/weight ratio of the material may be employed to full advantage. Such applications include the moulding of fuselage and even wings for larger radio-controlled models; and control-line models of the speed or Team Racer type where weight is not a critical factor. It may also be used for smaller mouldings, such as power model cowlings, etc. Considerable use is also made of

glass fibre as a reinforcement material applied over sheet balsa construction, such as in the strengthening of the front of a fuselage on a power model.

The standard adhesive for model aircraft construction is balsa cement. This, actually, is a cellulose adhesive which has the particular virtue of setting rapidly to produce very strong joints with porous woods. Its characteristics can be controlled by the amount and type of solvent, addition of resins to strengthen the cement, and so on. Thus there are various types of balsa cement, some very strong (and usually slower drying), others less strong, but perhaps with faster drying and setting. A "strong" balsa cement is suitable for gluing *all* woods. Other balsa cements may be excellent for use with balsa but less satisfactory on other materials, such as ply. Thus a strong balsa cement is a good general purpose choice. Some strong cements, however, contract considerably when drying and may warp or distort fragile balsa structures. In such cases it may be necessary to use another type of balsa cement.

Another type of adhesive which has come to the fore for model aircraft work is PVA, popularly described as "white adhesive" or "white glue." This gives excellent strength with all woods, does not contract or warp structures on drying, and does not form hard blobs or smears of surplus adhesive like balsa cement. Smears disappear on drying, and surplus cement can easily be wiped off after completing an assembly since PVA takes considerably longer than balsa cement to dry. This longer drying time can be an advantage when gluing up large surface areas, such as sheet covering, but increases construction time on other assemblies. PVA is an alternative to balsa cement for almost all model aircraft gluing jobs, but is employed mainly on larger models.

Special cements are used for gluing plastics—e.g. polystyrene can only be glued with polystyrene cement (usually called "plastic cement"); a thinned polystyrene cement or PVA is used for gluing expanded polystyrene; Perspex cement is used for gluing Perspex. Acetate sheet, being a cellulose plastic, can be glued with balsa cement.

For attaching tissue, silk or nylon covering, tissue cement may be used (a thinned-down balsa cement), dope (which again is a cellulose product rather like a very thin balsa cement), or dextrin-type pastes like photographic mounting paste, "Bondfix," etc. Choice is usually a matter of individual preference, the pastes being easier to use since they do not dry as rapidly as cements or dope, although the latter may make a neater job.

Only one other type of adhesive need be mentioned—the two-part epoxy resin capable of sticking virtually anything to anything. This is expensive, but enables glued joints to be made between materials which would otherwise have to be soldered, welded or bolted or riveted in place—e.g. for the attachment of small metal fittings, etc. The best-known adhesive of this type is "Araldite," which is a particularly useful addition to the model workshop for detail assembly jobs, etc.

Covering materials for built-up structures include tissue papers, silk and nylon. The tissues are special papers, not ordinary tissue. The lightest is Japanese tissue, particularly suited for the smaller, lighter models. Model tissues, somewhat coarser in texture but stronger, have been developed in a number of grades, but mainly "lightweight" and "heavyweight." The former are comparable in weight with Japanese tissue but absorb more dope in finishing, so produce a heavier overall covering. Their scope is virtually the same as Japanese tissue. Heavyweight model tissue is used for covering larger models.

Tissues represent the lightest covering materials for outdoor flying models, but are relatively brittle. Thus they are easily split or torn. Stronger materials, such as lightweight silk and nylon, are often preferred for larger models. These invariably weigh more than tissue coverings when doped and are also unsuitable for application over lighter structures since tautening under the action of the dope will produce warps. Nylon is considerably superior in strength to silk (which like tissue can become brittle with age and is not all that resistant to being split). Nylon chiffon is a favoured material for covering radio-control models and others of about 48 in. wingspan upwards. In selecting nylon for use as covering, however, it should be remembered that the lightest material is not always the best since the more open weave may demand a considerable

number of coats of dope to fill, each coat increasing the weight of the covering.

Other materials used for the finishing of model aircraft are described in Chapter 10.

CHAPTER 3

ALL-BALSA MODELS

THE most elementary form of model aircraft construction is that employing solid construction—that is, wings, fuselage, and tail parts are cut from solid balsa sheet, then shaped as necessary before being cemented together to form a complete model. There are definite limits to the size of such models, beyond which the weight of solid construction becomes prohibitive. However, "solid" construction may still be retained for components on larger types of models, such as wings and tail surfaces for control-line models, and fins for power models. The chief attraction of such construction is simplicity, with building time reduced to a minimum. Also the resulting structure is quite rugged.

The main classes covered by solid balsa construction are the toy flying models and chuck gliders. Toy flying models may be gliders (essentially similar in form to a chuck glider, and often so-called) (Fig. 13); or rubber-powered models (Fig. 14). In the former case size is usually limited to a span of about

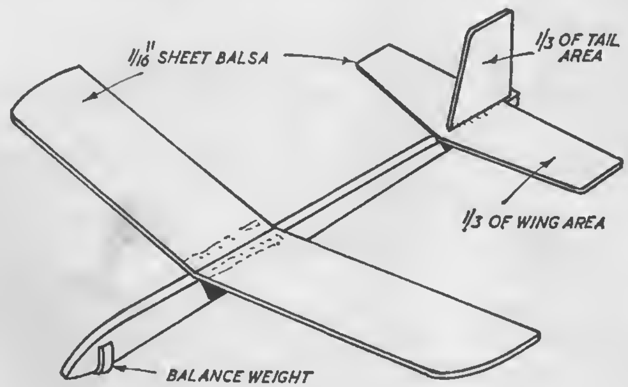


FIG. 13

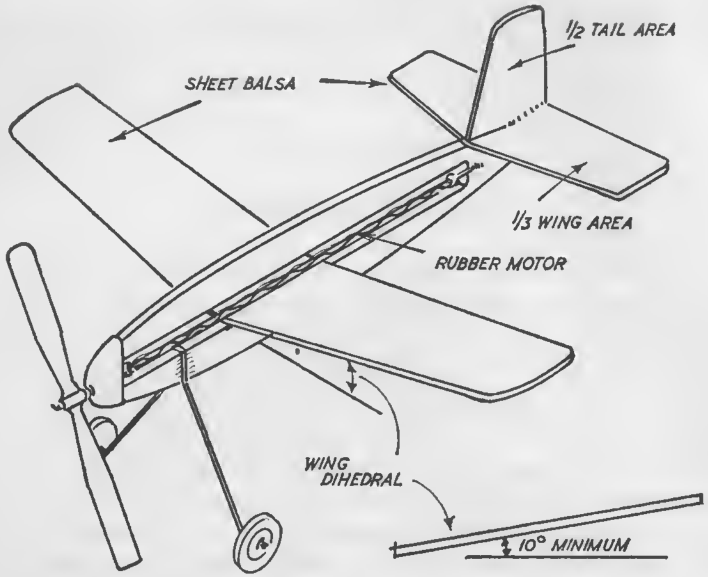


FIG. 14

9 or 10 in. so that thin flat sheet wings can be used (approximately 1/16 in. thick) with no attempt to shape them into an aerofoil section. Rubber models may be larger, in which case some attempt may be made both to stiffen and improve the efficiency of the wing by adding curvature or camber. This

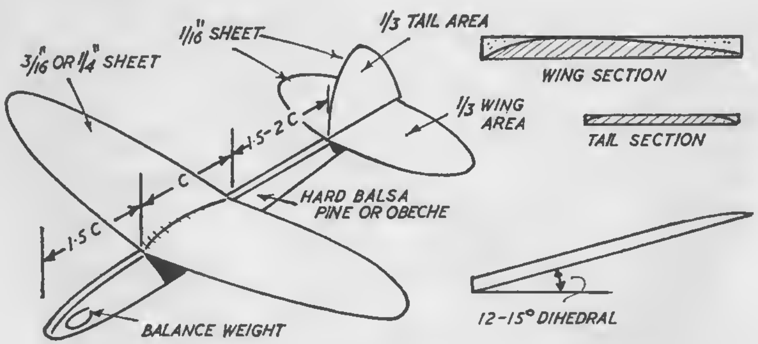


FIG. 15

may either be moulded in, or produced by cementing the wing panels to curved ribs.

The true chuck-glider, although still largely a "toy," is larger, with wings cut from thicker sheet balsa and carefully shaped to an efficient aerofoil section—Fig. 15. The model size is also larger and extreme care may be devoted to providing a fine, smooth finish by filling the grain of the balsa, rubbing down, and polishing—all aimed at improving efficiency.

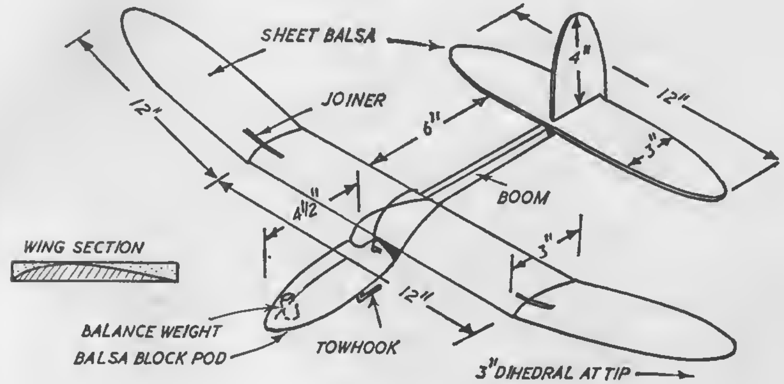


FIG. 16

The performance of such models can be quite amazing, with flights of 30 to 45 seconds obtained regularly with correct trim and launching technique—a sort of a "cricket-ball" throw upwards—and much longer durations possible under favourable conditions. They are an excellent type for the younger enthusiast to concentrate on since they are relatively inexpensive and easy to build, and also provide scope for trying out ideas in design layout, etc. Also they can be flown from comparatively small flying fields, such as a school sports ground or local park.

Above a wingspan of about 18 to 20 in. performance will suffer because of the weight of solid balsa construction for wings. However, for flying for fun, solid construction can be retained for gliders up to about 36 in. span. Too big for hand launching to any reasonable height, such models are towed up to a height by tow-line or a simple catapult (Chapter 4).

Design and constructional details normally follow on the lines shown in Fig. 16, with the emphasis on simple assembly allied to good aerodynamic shapes.

The success of such a model, apart from being basically sound in design proportions, depends very largely on correct choice of balsa—and so the type represents an excellent exercise in balsa selection. The wing panels represent the greatest wood volume, so the grade chosen should be very light in order

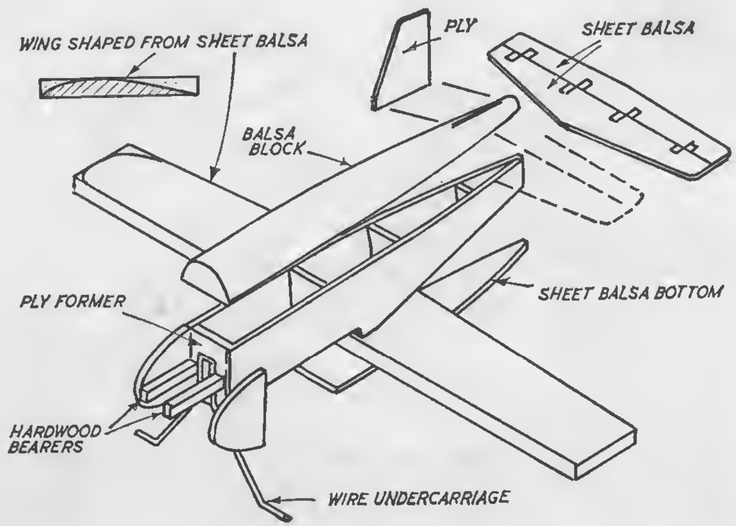


FIG. 17

to keep weight to a minimum. The "cut" is not so important since there is sufficient depth of section to provide strength against bending. Tailplane and fin parts should again be cut from very light sheet, this time quarter-grain for stiffness. The fuselage boom should be of hard or very hard balsa for maximum strength, with the other balsa blocks forming the "pod" section selected from the lightest balsa available.

For more advanced types of models sheet and block balsa construction may again be applied, but in somewhat modified form. This is particularly the case where total model weight is not too important, and simplicity and rapidity of construction

is desirable. The small- to medium-size sports type control-line model is a typical example (Fig. 17).

Here wings are cut from solid balsa sheet, shaped to a suitable aerofoil section just like a chuck glider wing. A light-medium or medium grade of balsa would normally be chosen in order to provide adequate strength with a relatively thin section. Tail parts are again cut from balsa sheet, this time thinner and only lightly shaped to an equivalent aerofoil section by rounding the leading edge and tapering the trailing edge. The fuselage, however, is built up as a hollow box from

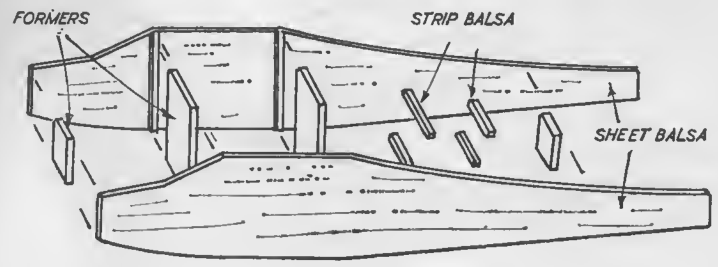


FIG. 18

sheet balsa sides and balsa blocks for the top and bottom. One or two sheet balsa formers are incorporated to shape the sides, together with a plywood front former which both carries and strengthens the motor bearers cemented to the sides, and forms an attachment point for the bent wire undercarriage. From this basic built-up box form, the fuselage is finally carved and sanded down to a suitable shape before attaching the wings and tail unit to complete the model.

Sheet fuselage construction is also popular for free-flight power models. Here the sides are cut from fairly thin balsa sheet of light or light-medium grade and then generally braced on the inside with strip balsa. The two sides are then joined by sheet balsa formers and cross braces or strips and finally covered with sheet balsa on the top and bottom after internal details and fittings have been completed (Fig. 18).

Again where weight is not critical, and something more attractive than a box shape is required, the fuselage top may

be covered with a light balsa block instead of sheet, carved to a rounded decking. This form of construction is often favoured for the larger low-wing radio-control models in order to arrive at a semi-scale appearance whilst retaining the simplicity of built-up box fuselage construction.

Solid balsa sheet construction is standard practice for practically all control-line models, regardless of size and type (although larger stunt models may employ built-up tissue or nylon-covered tailplanes to reduce weight). Sheet construction

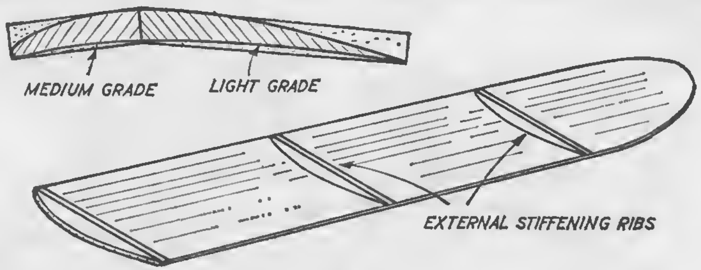


FIG. 19

is also widely used for power model fins and for glider fins, but not on fins for larger rubber models where weight-saving again is important (and fin areas are relatively large in any case). Solid sheet wings are also ruled out for all type of flying models, both free-flight and control-line, where the span exceeds about 20 in. (with certain exceptions in the case of sports models).

Normal construction in such cases is a built-up balsa frame which is subsequently covered with tissue (small or medium-size models) or nylon (larger models only). In many cases, however, wings may be partially sheet-covered, both to improve the efficiency of the wing by maintaining the aerofoil section over the front part of the wing, and also to add stiffness to the wing against bending. In some cases sheet covering may extend over the whole wing (e.g. larger control-line models and radio-control models).

Again there are exceptions. Some contest gliders employing very thin wing sections may employ all-sheet construction on the lines shown in Fig. 19. Although this implies a weight

penalty, by using thin balsa sheet of very light grade, overall weight need not be prohibitive and strength in bending is largely provided by the curvature or camber of the section. Such wings, however, are rather prone to flutter and can prove troublesome in this respect when the model is being tow-launched. They are not widely favoured as a consequence, but some excellent contest models have been produced em-

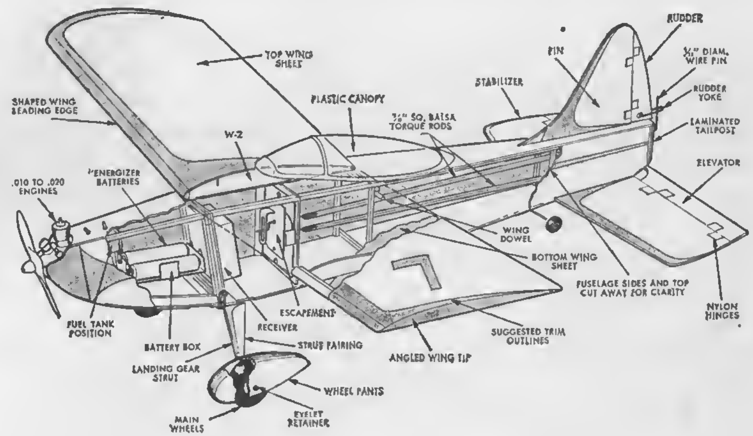


FIG. 20

bodying this form of wing construction. It is not recommended for the average builder since he will almost invariably produce a wing which is too heavy.

A form of all-balsa construction for wings which is becoming popular for small to medium-size radio-control models is, basically, a more or less conventional wing framework sheet covered top and bottom. However, instead of building the wing frame and then covering it with sheet, the wing is built directly on to the bottom sheet, thus simplifying assembly and making for greater accuracy. The resulting wing is heavier than a conventional built-up tissue-covered wing, but not all that much heavier, with suitable choice of balsa grade. It is considerably stronger and far more resistant to puncturing in sizes which would normally be only tissue-covered (not nylon-covered) anyway. However, for even better durability—and

ease in getting a good finish—it is usually better to tissue-cover such an all-balsa wing. The resulting increase in weight is negligible compared with the benefits.

All-balsa wing construction of this type is applicable to radio-control and sports type power models of between 20 and 48 in. wingspan as a typical range of sizes where it offers advantages without imposing an undue weight penalty. The model shown in Fig. 20 is an outstanding example.

CHAPTER 4

TOW-LINE GLIDERS

Tow-line gliders are the least demanding of all flying models and, of course, cost nothing to operate. As a consequence they are immensely popular and are built in a wide variety of types and sizes from about 2 ft. wingspan up to 10 or 12 ft. wingspan or more. As a general rule performance improves with size (this applying both to tow-line stability and flight performance), although a large model presents quite a problem as regards transport to and from the flying field, as well as costing more

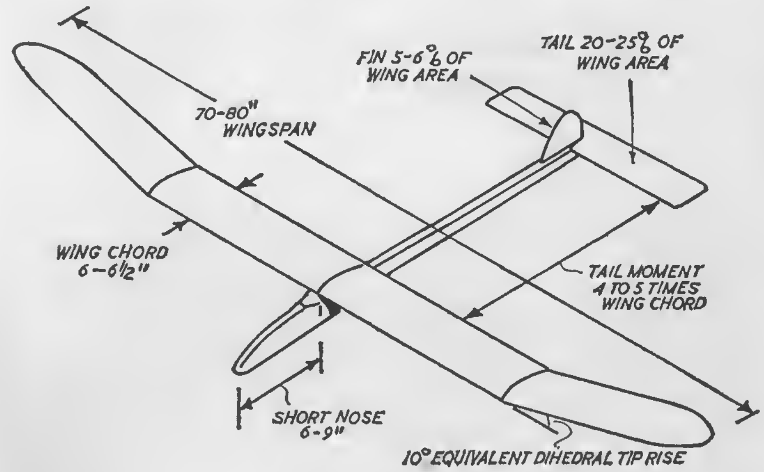


Fig. 21

initially and taking longer to build. A good average size, therefore, is between 4 ft. and 6 ft. wingspan, which range also embraces the main competition class (for A2 gliders, see Chapter 16).

Scale-type sailplanes are in general disappointing, for their

basic layout is unsuited to good model flying requirements. Basically their wings have too narrow a chord to be efficient scaled down to model sizes, and are difficult to make strong enough and light enough with model construction. Also their fuselages are too short and tail areas too small to suit model stability requirements. All the best model gliders, therefore, are normally original designs and top performance is realized

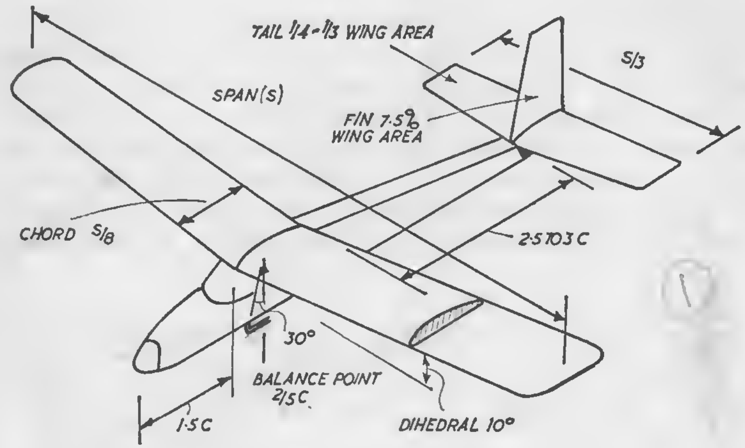


FIG. 22

by the highly specialized contest designs employing what are virtually "stick" fuselages and typically model-type aerofoil sections (Fig. 21). These are representative of the A2 class.

Other original designs may employ more orthodox proportions, conforming to typical values summarized in Fig. 22. Fuselage shape is relatively unimportant, giving considerable scope for individual preference in design ranging from functional (e.g. a basic "stick" fuselage of minimum cross section) to semi-scale layouts, etc. Some common variations are shown in Fig. 23.

Gliders to the A2 contest specification are limited in total area (i.e. combined area of the wings and tailplane). In order to get the most efficient disposition of area designers usually concentrate on putting as much of the total area as possible into the wings, reducing tailplane area to the minimum possible

consistent with satisfactory stability. Since tailplane "power," as regards its stabilizing or corrective effect, is equal to its area multiplied by the distance of the tailplane from the centre of gravity or balance point of the whole model (tail moment arm), "power" and thus stability can be maintained with a smaller tailplane area by increasing its moment arm. This leads to the typical long-fuselage glider design, so different from that of a full-size sailplane. To reduce the surface area and thus the drag of a long fuselage, the cross-sectional area is kept down to a minimum— hence the "stick" appearance. In

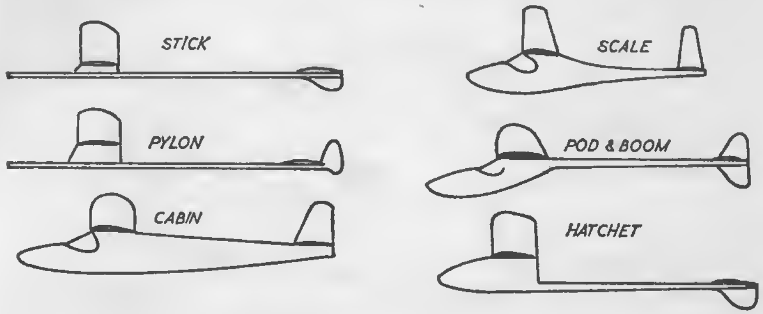


FIG. 23

order to balance the weight of this long fuselage its length may also be extended forwards a considerable distance, so that a smaller nose weight is needed for balance.

Such considerations as these can lead to extremes in design, but the general pattern for A2 gliders is as shown in Fig. 21. Wing-aspect ratio (ratio of span to chord) is higher than with other types of models, to increase wing efficiency, but limited by the fact that wing chords under about $3\frac{1}{2}$ in. are very inefficient, as well as by structural considerations.

The more orthodox gliders may not have the same still-air performance, but can be equally satisfying for sports flying, particularly as longer tow-line lengths can be used to get greater height from a launch and thus longer flights. In suitable weather flight duration can be enhanced by thermal currents, when a well-trimmed model may soar to a considerable height and quite commonly fly away out of sight, unless fitted with a

device to bring it down after a predetermined time (see Chapter 11). This applies to all free-flight models, but tow-line gliders in particular rely on thermal currents to prolong flight duration.

An essential feature of any tow-line glider is that it should be stable enough to tow up straight for launching. The method of launching is to lay out a suitable length of tow-line (usually thread or nylon fishing line) in a downwind direction. The end of the line is tied to a wire loop or ring which hooks on to a tow-hook in the bottom of the glider fuselage. A streamer of silk, nylon, or similar light cloth is also tied to the line near the ring (Fig. 24).

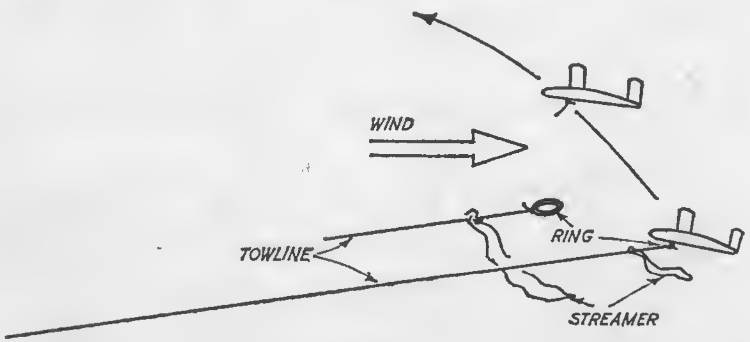


FIG. 24

With a helper holding the model, the launcher then runs forward into the wind—and at the same time the helper releases the model in a slightly nose-up attitude with the wings level. The launcher then continues to tow the model forwards and upwards, in a similar manner to flying a kite. The speed at which the launcher moves forward depends on the speed of the wind and the size and weight of the model. The model must not be towed too fast, otherwise it will overstrain and possibly break the wings. At the same time it must be towed fast enough through the air to climb to the full height of the tow-line, when a slackening of the tow-line will allow it to slip the ring off the tow-hook and commence free flight.

If the tow-hook position is not correct, or the model is badly designed or trimmed, it will not tow straight. Instead it may

veer off to one side and sideslip into the ground for a damaging crash landing. Alternatively, it may veer from side to side on the tow-line, eventually slipping off prematurely.

The first requirement is that the model should be trimmed for straight flight, as any tendency to turn will be exaggerated by the increased speed when towing. The best tow-hook position can only be determined by experience with a particular design. It is normally on a line about 40 degrees from the balance point, in the centre of the bottom of the fuselage (Fig. 25). If too far back, the model will tend to pull off to

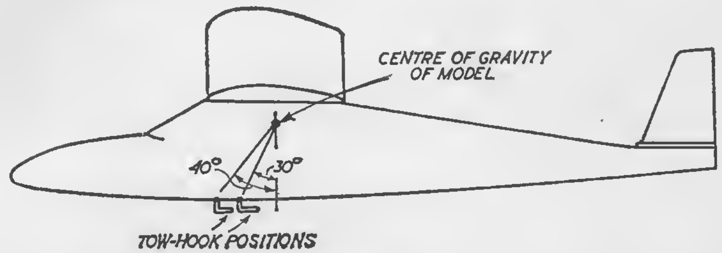


FIG. 25

one side or the other. If too far forward, the model may veer from side to side. The optimum position is affected by changes in balance point or trim, and may need to be farther forward for windy weather than calm weather. Often, therefore, alternative tow-hook positions are provided on a glider, or provision made to adjust the tow-hook position.

Even with a correct tow-hook position a glider will not tow up straight if the wings or tail are warped or out of line. These are rigging faults which must be corrected, if satisfactory tow-launching is to be achieved. Also there may be a basic fault in the design which makes it unstable under tow. The only cure then is to correct the design fault—having first established that the lack of tow-line stability is not due to warps—such as by adjusting the fin area. A simple increase in fin area, however, is not an automatic cure. Many smaller gliders suffer from "marginal" tow-line stability so that the slightest inaccuracy in construction and trimming makes them difficult or impossible to tow properly. Larger models of good design

should not suffer from this as an *inherent* fault, although the degree of tow-line stability in different designs may vary considerably.

It will be appreciated that having trimmed a model glider for straight flight to get a straight tow, it will then also fly in a straight line when released at the top of its launch (which, incidentally, with a good model and the tow-hook far enough

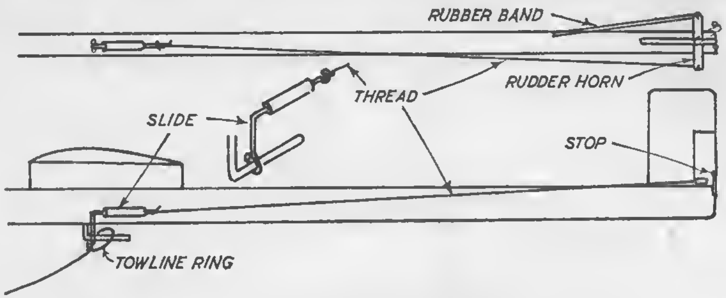


FIG. 26

back, should be almost overhead of the launcher so that the model has climbed to a height equal to the full length of the tow-line). There are two basic methods by which a straight tow can be followed by circling free flight.

(i) Putting the tow-hook on one *side* of the fuselage and trimming for a straight tow by offsetting the rudder to compensate for the offset pull.

(ii) Using an auto-rudder device which pulls the rudder straight for the tow launch but allows it to move to a position for turning flight when the model commences free flight.

Method (i) is not a satisfactory solution, for the offset effect will vary with different wind strengths and towing speeds. An auto-rudder device is much more reliable and is quite simple to rig. The basis of all such devices is that the rudder is hinged and pulled in one direction by a light rubber band attached to a rudder horn (Fig. 26). An adjustable stop is fitted to limit the movement to that required for steady circling flight. A line is attached to the other side of the rudder horn and taken either to a ring which slips over the tow-hook in front of the tow-line ring; or to a lever which is moved fowards to pull the rudder

straight and locked by a wedge for tow-launching. This wedge is attached to the tow-line by a short length of thread.

With the first method, all the time the tow-line is pulling forward on the tow-hook it will also pull the rudder-line forwards, holding the rudder straight. Once the tow-line falls clear, the rudder is pulled over into the turn position. With the second method the rudder is locked in a straight position until the tow-line falls off. In releasing from the model it also pulls

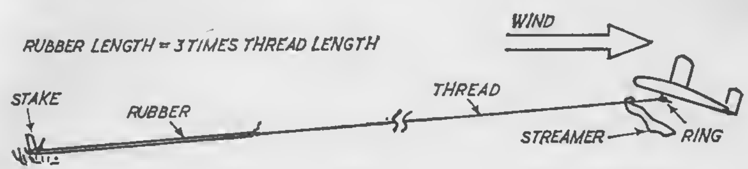


FIG. 27

out the wedge holding the lever locking the rudder in the straight position, again allowing the rudder to move to the turn position. There are other variations on these themes, but all work in a similar manner.

Tow-launching is essentially a two-person affair—one to hold the model and one to move forwards with the tow-line. To assist in recovery of the line ready for the next flight it is usual to tie the free end of the tow-line to a simple winch. Thus, when the model is released, the line can be reeled in rapidly. For single-handed launching a catapult may be used, although this is rather more restricted in the length of line which can be employed, and in the height gained by the launch.

The basis of a catapult is a length of rubber strip tied to a stake which is pushed into the ground, the other end of the rubber being tied to a length of tow-line. The best proportion of rubber-length to line-length is about one to four to one to three—i.e. a 100 ft. length of tow-line will need about 25 to 33 ft. of rubber tied to it. It is important that the catapult rubber is not too strong. Rubber strip $\frac{1}{8}$ in. wide is quite adequate for launching medium-size models via a 100-ft. tow-line. Larger models may need 3/16 in. or possibly $\frac{1}{4}$ in. strip. It is better to have the catapult rubber too weak rather than too strong as if it is too strong it will be difficult or even impossible

to achieve a satisfactory launch. A weak catapult, on the other hand, may well produce successful launches with a model which has insufficient tow-line stability for satisfactory running launches with a conventional tow-line.

For competition work the length of tow-line is limited (Chapter 16) and a running launch is specified. Flying for fun, however, either type of launch can be employed, and with a running launch the length of tow-line can be selected to suit the conditions, and the size of the flying field. Launching heights of less than about 100 feet are seldom satisfactory, except on dead calm days, since air near the ground is always turbulent and models do not perform at their best under such conditions. Longer lines giving launching heights of 200 to 300 ft. are far more satisfactory. Provided there is sufficient space available, and a very light line is used, tow-line lengths of up to 500 ft. or more can be used. With very long line-lengths, however, it will become increasingly unlikely that the model can be towed up to the full height of the line and it may have to be launched with considerable sag remaining.

As regards towing technique, this is something which can only be mastered with practice. The first thing is to get the model stable under tow, and then to practise technique. Basically, the launcher should aim to tow the model at a *minimum* speed consistent with it moving forwards and upwards. Any excess speed is only overstressing the wings and will tend to show up any discrepancies in trimming or rigging. In windy weather it may even be necessary to move towards the model, rather than tow it forwards, in order to keep its *speed through the air* down. And if the model does get into difficulties, the best way to save it is either to move rapidly *towards* it to reduce the pull on the line or to release the model immediately.

There are other variations on tow-launching, such as starting with a long length of line and winching it in instead of running with the line. This has some virtues for sport flying. Pulley launching systems are also sometimes used with larger models, but the complication is seldom justified and there is less control over the model than with conventional tow-line launching.

The whole basis of tow-line launching is, of course, simply

to get initial height from which the glider can start free flying and thus turn in a satisfying flight duration. Scope for "high start" launching is also provided by hills, where the model can be hand-launched. With a suitable terrain, and the right type of model, it is possible to make a model slope-soar by launching outwards from the slope into the wind direction. This does, however, demand a model with good "weathercock" stability to continue heading into the wind, rather than circling back into the side of the hill.

The best possibilities here are realized by fitting the glider with radio control when it can be "tacked" up and down the windward side of the slope, maintaining or gaining height in the upward deflected air in front of the slope. In this respect the model is duplicating the performance of full-size sailplanes and, with the proper type of model and suitable conditions, very long flight durations can be put up.

Equally, of course, radio-control gliders can be tow-launched from level ground, when the control available is largely directed towards keeping them within bounds, as well as circling and taking advantage of any thermal lift which may be present.

CHAPTER 5

RUBBER-POWERED MODELS

WHERE maximum performance is the aim the success of a rubber-powered model depends primarily on (i) very low structural weight and (ii) the use of a relatively large rubber motor. Ultimate performance—ignoring thermal assistance—is also related to the size of the model. The bigger the model, in general, the better its potential still-air flight duration, although there is a definite upper limit at which the corresponding size of rubber motor becomes too large and too powerful both to wind comfortably and to be accommodated in a conventional fuselage structure. This upper limit is represented by a model size of about 300 sq. in. wing area. The best performance is usually given by a somewhat smaller model (around 200 to 220 sq. in. wing area), this size corresponding to the Wakefield International specification, although the current Wakefield specification restricts rubber weight (Chapter 16). This restriction on rubber weight was introduced because Wakefield models as originally developed had *too* high a performance, being readily capable of 4- to 5-minute flights without thermal assistance and presenting problems as to the space required for flying them.

A minimum structural weight demands the use of built-up tissue-covered structures throughout, and particular attention to the selection of balsa wood grades and "cut." Wood sizes are also reduced to a practical minimum so that the "maximum performance" rubber model is somewhat flimsy and readily damaged if maltreated. Rubber weight may account for one-half the total weight of the model—thus a 44 to 48 in. span high-performance rubber model may only weigh 8 ounces complete, of which 4 ounces is accounted for by the rubber motor and 1 ounce by the propeller, leaving only 3 ounces for the whole airframe.

To absorb the power of such a heavy rubber motor and give a long motor run (up to two minutes duration) a large propeller is needed, the diameter in such cases approaching one-half of the wingspan. A generous amount of dihedral on the wings will be needed to counter the torque of such a large propeller, and both tailplane and fin areas will need to be relatively large. The design may therefore end up as a true "original," looking very different from any full-size aeroplane

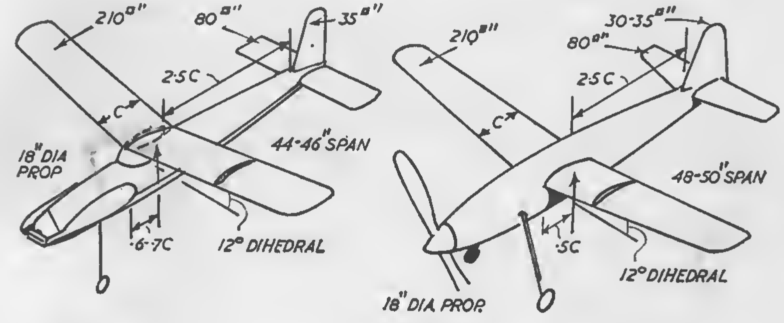


FIG. 28

(Fig. 28). Usually, too, since the very large propeller would represent a prohibitive drag penalty when the power ran out, the propeller blades are arranged to fold back as soon as the model commences gliding flight.

With the change in the Wakefield formula this type of high-performance rubber model has virtually disappeared, except for "open" contests. It does, however, represent about the most efficient type of flying model aeroplane ever produced, with an absolute premium on skilled design and construction. It can obviously be beaten for sheer performance by a power model where the engine can run just as long as you want the model to climb, and because performance can be obtained far more readily in this manner the power model has become far more popular.

Restricting the rubber weight whilst retaining a minimum model weight, as in the current Wakefield contest model formula, means that structural weight can be increased for a

given size, and thus the airframe can be made stronger. Performance is also restricted as a consequence, and the type becomes a highly specialized contest type with limited appeal, and all designs conforming to a more or less similar basic layout (Fig. 29).

For "sport" flying—as opposed to contest flying—a more rugged model is desirable, involving an increase in the airframe weight. In order to avoid an excessive total weight,

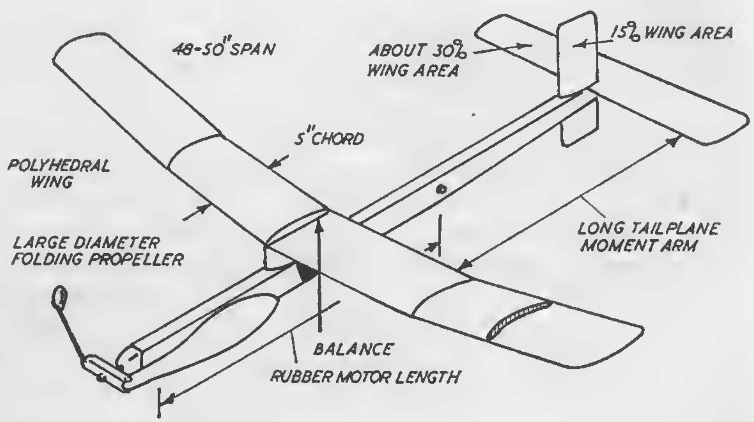


FIG. 29

rubber weight is decreased, again leading to some loss in performance. Also, since the rubber motor is smaller the propeller can be made smaller in diameter—with a diameter down to one-third of the wingspan, for example.

A typical model of this type can still have a very good performance, and may even be given a semi-scale appearance by the incorporation of a cabin in the fuselage shape. To avoid the complication of a folding propeller the propeller can be made to freewheel or "windmill" at the end of the power run, and so reduce its drag in this manner. If the model is designed primarily for performance, then the undercarriage may be omitted entirely (as on virtually all modern contest models). If it is a semi-scale type an undercarriage is fitted, although the length of leg necessary to provide ground clearance for the propeller will represent a considerable departure from "scale"

proportions. Fitted with an undercarriage, however, a rubber model will take off successfully from any flat and reasonably smooth surface, which itself is a "realistic" feature.

Constructional features of a typical "general purpose"

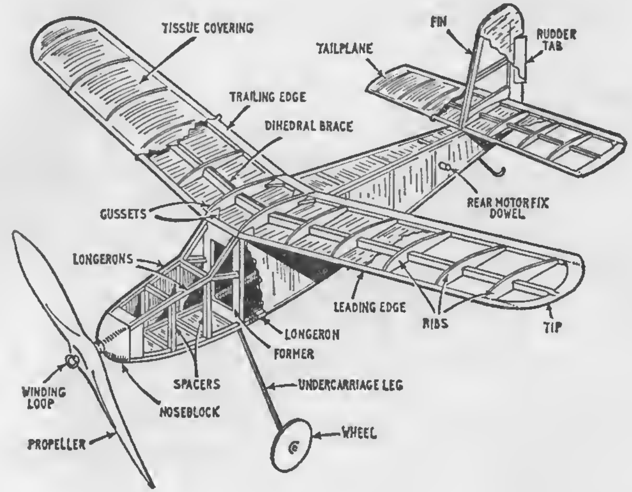


FIG. 30

rubber model of small to medium size are shown in Fig. 30. This is basically a "duration" design aimed at giving a good flight performance, but using a freewheeling rather than a folding propeller, and retaining an undercarriage. Other types will normally follow a similar form of construction but may trend more towards "original" or "semi-scale" features. In the former case a larger diameter folding propeller would be used (normally a single-blade propeller with counterweight for simplicity), polyhedral used on the wing instead of dihedral, the undercarriage omitted, and the fuselage shape reduced in cross-section (probably mounting the wing on a pylon). For a semi-scale variant the fuselage shape would be made more "realistic," even if this meant an increase in bulk and weight. More attractive outline shapes may also be used for the tailplane and fin, and possibly the wing tips. The model design would, in fact, be "styled" around similar basic proportions.

A similar form of construction is used again in the rubber-powered flying scale model. A good compromise between scale realism and model requirements is, however, difficult to achieve. The necessary increase in tail areas may not be obvious if the same outline shapes are retained, but there is no escape from the fact that the wing dihedral *must* be increased from the

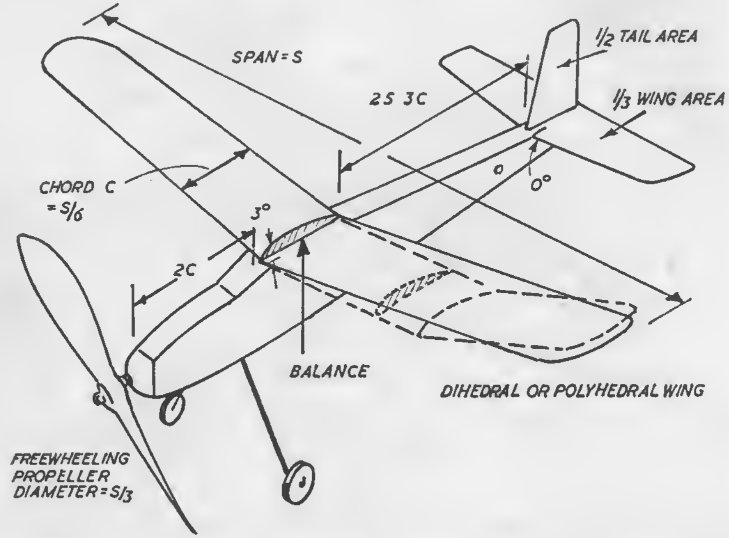


FIG. 31

scale value, and the undercarriage length increased to accommodate a suitable size of propeller. If the propeller diameter is reduced (to preserve a more realistic undercarriage length) performance will automatically be reduced since the matching size of rubber motor will also be reduced. Thus although the rubber-powered model is attractive from the point of view of basic simplicity and low cost, it is not particularly suited to flying scale designs. Power models are much better in this respect, although similar stability problems are involved.

Typical design proportions for an original rubber model are shown in Fig. 31. Corresponding dimensions for typical model sizes can be worked out from the proportions summarized in Table VI. Actual shapes are largely immaterial, provided they

TABLE VI. DESIGN PROPORTIONS FOR RUBBER-POWERED MODELS
(Proportions given relative to Span dimension "S")

TYPE	Wing Span S	Wing Chord	Tail Moment[1]	Nose Length[2]	Fuselage Length	Tail Span	Fin Area	Tail Area	Prop. Dia.
DURATION	30–48 in.	S/8	2·5 to 3 times wing chord	S/5 to S/4	$\frac{3}{4}$S	2/5S	15% of wing area	35–40% of wing area	2/5 to $\frac{1}{2}$S
SEMI-SCALE	20–48 in.	S/8	2·5 times wing chord	S/4	$\frac{3}{4}$S	2/5S	15% of wing area	33% of wing area	S/3

[1] Distance between trailing edge of wing and leading edge of tailplane.
[2] Distance to noseblock from leading edge of wing.

are not exaggerated. Thus rectangular outlines are normally chosen for the wings and tail of a "duration" model because they are simpler to build and usually represent the lightest and strongest structure. Curved tips may, however, well be employed on a semi-scale layout. For similar reasons, the fuselage of a "duration" model is usually made as a simple box of minimum cross-section (large enough to accommodate the rubber motor), but still mounting the wing well above the centre line of the fuselage on a simple built-up structure or

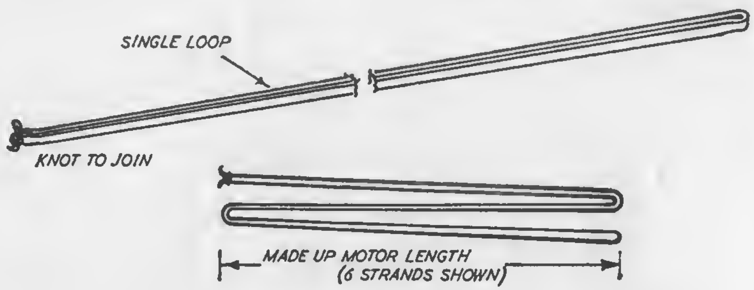


Fig. 32

pylon. A deeper fuselage would be used on a semi-scale design, so that the wing rests on top of the cabin area. Any attempt to improve the appearance of the fuselage by using a rounded section rather than a pure "box" will, however, complicate the structure and add weight. The other main difference between the "duration" and semi-scale types will be in propeller diameter, as previously discussed.

Rubber motors themselves are worthy of detailed description for they represent the heart of the model, and rubber itself can vary a lot in quality and performance. This is even true of "aero strip," or rubber specially produced for model aircraft applications. It is called "aero strip" or "rubber strip" because the section is invariably flat (rectangular) in standard widths of $\frac{1}{8}$, $\frac{3}{16}$, and $\frac{1}{4}$ in. and either 1/24 or 1/30 in. thick.

Rubber motors are normally made from one long length of strip tied together at the ends to make a continuous loop and then folded or doubled back on itself a number of times to make a motor of so-many individual *strands* (Fig. 32). Thus the length

of rubber strip required is equal to the made-up motor length multiplied by the number of strands.

The number of strands required, and the size of the strip section, is determined by the size and weight of the model and by the propeller diameter and *pitch.* Propeller *pitch* refers to the angle of the blades, or, more correctly, the theoretical distance the propeller would advance in one revolution if screwed into a solid medium (like a screw being screwed into wood). The power of a large rubber motor may be absorbed by increasing propeller diameter *or* pitch. Thus, for example, a 44 in. span model may employ an 18 in. diameter propeller with a high pitch (1·75 to 2 times the diameter); or, say, a 24 in. diameter propeller with a medium to low pitch (1·5 to 1 times the diameter). Such factors can only be worked out by experience, but for any given design a propeller size is always specified, together with the required power (number of strands in the motor). Table VII can also be used as a general guide.

No recommendations of this kind can be exact. If the model is heavier than expected it may need a greater number of strands in the motor. If it works out lighter it may be possible

TABLE VII. TYPICAL RUBBER MOTOR SIZES

Duration Model	30 in.	36 in.	40 in.	44 in.	48 in.
Prop. Dia. (in.)	12–14	15	16	17–18[2]	18–19[3]
No. of Strands of $\frac{1}{4}\times 24$ Strip[1]	8	10–12	12–14	14	16
Semi-scale Model Span	18–24 in.	24–27 in.	27–30 in.	30–33 in.	33–36 in.
Prop Dia. (in.)	6–8	8–9	9–10	10–11	11–12
No. of Strands of $\frac{1}{4}\times 24$ Strip	2–4	4–6	6–8	8–10	10–12

[1] Or equivalent in other sections.
[2] 20–22 in. dia. with low pitch.
[3] 22–24 in. dia. with low pitch.

to reduce the number of strands (using the same weight of motor) or increase the propeller diameter, either of which could improve performance. Also if you "guesstimate" wrongly in an original design you may have to adjust the number of strands in a motor, this being simpler than carving a new propeller.

Made-up motor *length* is rather arbitrary. Using a maximum

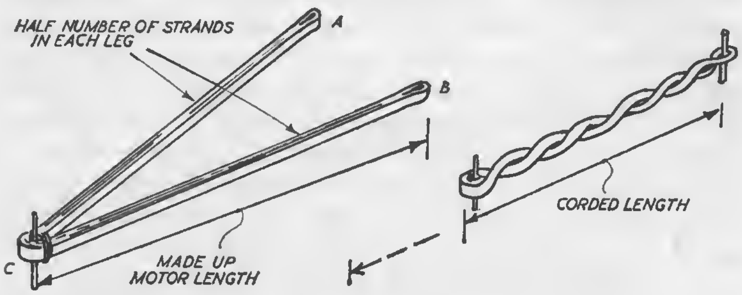


FIG. 33

rubber weight for best duration performance, length will follow automatically from the number of strands required. For all other models a good general rule is that made-up motor length should be approximately the same as the wingspan, provided the model has orthodox proportions. This will ensure a reasonable size of rubber motor. It can, of course, be shorter, but this will detract from performance. It can also be longer, but this will also increase rubber weight and thus model weight, and call for extra strands, again increasing weight.

A satisfactory motor length, therefore, is invariably longer than the distance between the propeller shaft hook and the rear rubber anchorage in the fuselage, unless the fuselage is deliberately made long enough to accommodate this length. This is, in fact, done on some high performance designs, and particularly on contest designs with a "limited rubber" rule. With the average model, however, the motor length is always longer than the distance between anchorage, which means that when the motor is unwound it will lie unevenly on the bottom of the fuselage and almost certainly upset the balance for gliding flight.

A simple and very effective method of accommodating this slack is by "cording" the motor. To do this the motor is laid out in two "legs," each having half the required number of strands (see Fig. 33). The middle point (*C*) is lightly bound to a suitable marker (such as a short length of dowel) with a rubber band, the complete motor is opened up, end *B* held and a winder attached to end *A* to wind on about 100 to 200 turns (depending on the actual length of the motor—experience will indicate the actual number of turns required). Ends *A* and *B* are then brought together again (putting end *B* on the winder hook), and the motor pulled out fairly taut by holding at *C*. Release the winder and allow the motor to unwind, when it will twist up into a "cord" much shorter in length than the original motor length. Each end of the corded motor *C* and *A* and *B* together is then bound with a rubber band to hold it in place, when the motor can be inserted in the fuselage. It can then be wound up fully in the normal way. On unwinding it will always revert to its shortened "corded" form and thus never fall slack in the fuselage.

If it *is* still slack then more "cording" turns are required. If it is too tight between anchorages when unwound, then too many "cording" turns have been used. This is not necessarily a bad thing, except that the number of cording turns put on reduces by a similar amount the number of turns you can wind up the motor. Thus to get maximum number of winding turns from a rubber motor use a minimum number of "cording" turns—just enough to take up the slack when unwound.

The number of turns which aero-strip will take can be estimated from Table VIII. This gives maximum turns for a complete range of number of strands in all standard strip sizes and allows about 10 per cent safety margin. That is, the table figures are lower than the number of turns to break the motor, but they refer, of course, to good quality strip in good condition and *properly lubricated and broken-in.*

Lubrication is important both for achieving maximum turns on a rubber motor and for preserving its life. An unlubricated rubber will chafe on being wound, and readily break up. The only lubricants which should be used are special rubber lubricant (based on soft soap and glycerine mixtures) or *castor* oil—

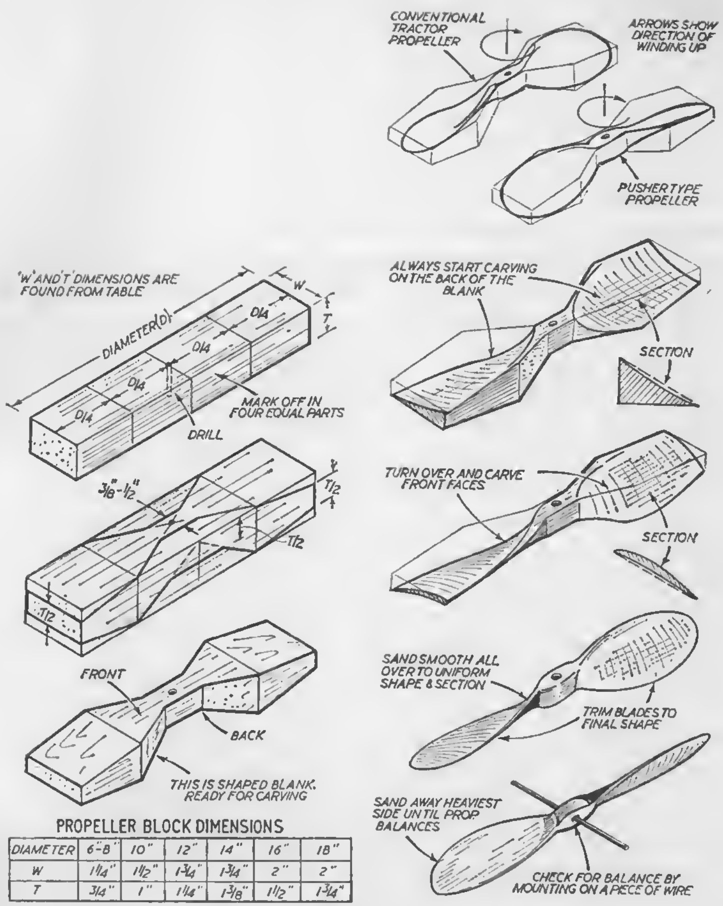
never ordinary lubricating oil or grease which will only attack and rapidly destroy the rubber. Lubricant should be well rubbed into the motor immediately after making up into the first large loop (not before, since it is difficult to get knots to hold in lubricated rubber without binding with wool). Use

TABLE VIII.
MAXIMUM SAFE TURNS FOR RUBBER MOTORS
(No. of turns per inch of motor length)

Number of Strands	Rubber Strip Section				
	$\frac{1}{4}\times 24$	$\frac{1}{4}\times 30$	$\frac{3}{16}\times 24$	$\frac{3}{16}\times 30$	$\frac{1}{8}\times 30$
2	60	63	66	72	90
4	46	47	49	51	63
6	36	39	41	44	51
8	30	33	35	37	44
10	26	29	31	33	38
12	24	28	29	31	36
14	22	25	27	29	33
16	20	25	26	27	30
18	—	24	24	27	30
20	—	—	23	26	29
22	—	—	21	25	28
24	—	—	—	24	26

enough lubricant to wet all the rubber thoroughly and then wipe off any surplus. Relubricate whenever the rubber appears to be drying out.

A new rubber motor will break at about two-thirds or less of its normal maximum turns if you attempt to wind it right up first time. It must, therefore, be broken-in carefully, which means winding up to something less than half maximum turns and letting unwind; repeating with about 10 per cent additional turns; and so on until you have reached 80 to 90 per cent maximum turns. This will normally involve some five separate windings and unwindings, after which the motor can be installed in the model ready for use.



DIAMETER	6"-8"	10"	12"	14"	16"	18"
W	1 1/4"	1 1/2"	1-3/4"	1-3/4"	2"	2"
T	3/4"	1"	1 1/4"	1-3/8"	1 1/2"	1-3/4"

FIG. 34. CARVING A PROPELLER

This is one of the trickiest operations in constructing a rubber-powered model. The basic steps involved are—

(i) Mark out and cut a *block* of the correct proportions.
(ii) Mark out the block and cut to a *blank* shape.
(iii) Carve the blank edge-to-edge to produce a correct propeller form.

There is also an art in winding a rubber motor. Apart from convenience, a winder is essential to put on maximum turns since the motor must be stretched as it is wound—known as stretch winding. At the commencement of winding the motor need be only lightly stretched, but the operator should then move outwards from the motor until the motor is stretched to at least three times its original (made-up) length. Hold this position until one half to two-thirds the number of turns required have been wound on, then advance towards the model slowly as the remaining turns are applied. This will not only enable more turns to be put on without over-stretching the motor but will also result in more even winding.

CHAPTER 6

POWER MODELS

WITH such a wide choice of miniature internal combustion engine sizes available a power model becomes a practical proposition in sizes from a little more than 1 ft. wingspan upwards, with motor run limited only by the size of the fuel tank. There is seldom any question of not having enough power; usually the reverse is true, so the problem of building down to minimum weights for maximum performance does not arise. As a consequence, power models are generally more robust than either gliders or rubber models, and can also make use of simplified construction techniques, as described in Chapter 2.

Small-size power models do, however, have their limitations, being mainly suited for calm-weather flying. They are also generally unsuited for competition work where motor run is restricted to a matter of 10 seconds or so, and flight duration depends largely on efficient model design capable of achieving a very rapid rate of climb on the power available, followed by a prolonged glide. Engine efficiency, too, increases with engine size, again leading to better climb performances. On the other hand the small model, because of its light weight, can often take a lot of rough treatment in the matter of crash landings without damage whereas a larger model might suffer serious damage under similar circumstances. Small-power models therefore, have a particular appeal for "sports" flying in sizes up to about 40 in. span. Competition model sizes are usually based around the recognized maximum engine sizes in the competition classes (typically 1.5 c.c. and 2.5 c.c., the latter being the International maximum size).

Free-flight power models fall into three definite groups—original designs based on achieving maximum duration performance; semi-scale models; and scale models. The groups are quite distinct, although there is not all that difference

between semi-scale and scale as regards basic layout, matching engine sizes, and performance. The duration models on the other hand are an entirely separate type and completely unrivalled as regards sheer performance potential.

The chief requirement in this latter respect is a design layout stable enough to be able to accommodate the considerable power available from the matching size of engine—power which may result in a climb performance of several thousand feet per minute (although, as noted, engine run is restricted to a fraction of a minute for competition work). The design layout which has proved most capable of controlling such power is the

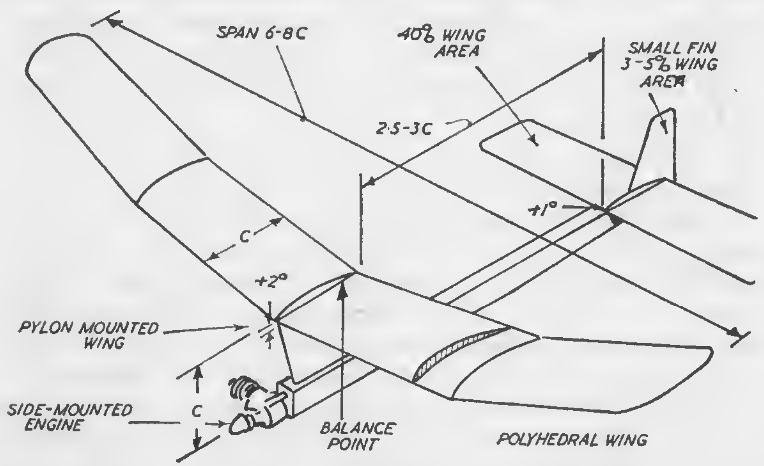


FIG. 35

pylon configuration, as shown in Fig. 35. Note that in addition to being mounted well above the fuselage and right forward (just behind the engine), polyhedral is also standard, with generous dihedral angles on the outboard panels.

There are variations in proportions, such as in fuselage length, fuselage shape, and mounting the engine in line with the wing in a nacelle rather than on the fuselage, but the basic pylon layout remains the standard. The modern trend has been towards reducing the cross-section of the fuselage to "stick" proportions (normally hollow sheeted box construction), which emphasizes even more the pylon configuration

and tends to give all such original designs a very similar appearance. Main differences, in fact, are usually in the structure.

Other configurations are not excluded completely, but are invariably trickier to trim and need intensive development to be brought up to comparable contest performance standard. Virtually every possible alternative configuration has been tried, but the pylon model still remains the normal and safest choice.

It will also be appreciated that no attempt to add semi-scale feature to such a layout can provide more than a gesture towards "realism"; and any attempt to modify the proportions in order to achieve realism can only drastically detract from the stability margin provided by the original layout. In practice, this means that a semi-scale model although retaining perhaps a similar wing and tail cannot accommodate the same engine power without becoming unstable. It cannot, therefore, begin to compete as regards contest performance. Thus the semi-scale model is basically limited to non-contest flying; or in further developed forms for radio control (see Chapter 14). It is, however, far more popular in numbers, and is also far less exacting to trim. Although the pylon layout provides additional stability, it is still a tricky model to trim with a powerful engine and requires considerable experience to handle successfully. On the other hand, for a modeller who is seeking "duration" performance rather than "realism," the duration-type model fitted with a smaller and less powerful engine can be a safe and easy model to fly.

Typical proportions for a semi-scale power model are shown in Fig. 36. A high-wing cabin layout is the most popular choice since this basic configuration has a reasonable degree of stability to start with. Shoulder-wing models can be a little more tricky to design and trim, and low-wing models even trickier. The latter do not, in fact, normally make good free-flight models, although with careful development and attention to specific requirements (such as an increase in dihedral angle compared with high-wing models and readjustment of fin area to balance) they can be suitable for sports models. Because the stability margin is less than in a high-wing monoplane, it is also desirable to reduce the power, that is, to use a smaller

engine in the same size of model, compared with a typical high-wing monoplane, or make the model larger for the same size of engine.

Somewhat similar considerations apply to biplane models. Stability is generally better than that of a low-wing model, but the shorter wingspan provides less control for the torque of the

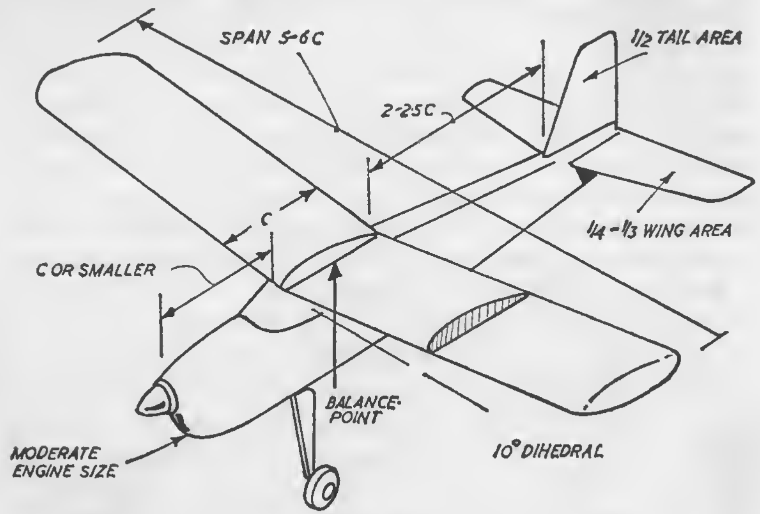


Fig. 36

motor. To compensate for this the model must not be underpowered rather than overpowered (which would only aggravate the rolling action of torque).

With a scale model the difficulties of obtaining stable flight are usually exaggerated, unless the designer is prepared to sacrifice true scale outline and appearance in order to arrive at what approximates fairly closely to semi-scale proportions. The two chief difficulties arise with regard to wing dihedral and tail areas. For satisfactory automatic stability a high-wing free-flight model needs a minimum of about 8 degrees of dihedral, and 10 degrees is better still. A shoulder-wing model will need more dihedral, and a low-wing model more still (as much as 15 degrees). Full-size aeroplane wings generally have very small dihedral angles, perhaps only a matter of a degree or so on high wing layouts.

Increasing the dihedral above the true scale value will alter the appearance, and is in any case a departure from true scale. A secondary effect is that increasing the dihedral must also be followed by increasing the *fin* area, to balance the additional side area of the wings. The fin size will probably be too small for model stability requirements to start with, so it may need increasing by a substantial amount to arrive at a stable model layout. The tailplane will also almost certainly be too small for

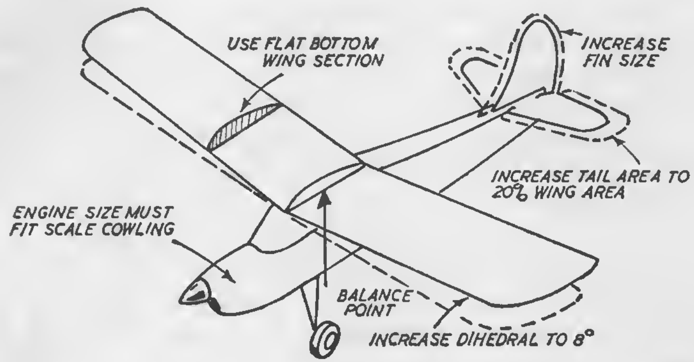


Fig. 37

model stability—it needs to be *at least* one-fifth of the wing area, and even bigger to be on the safe side.

On this basis it is a wonder that flying-scale models will fly at all! There is also one further difficulty. Relatively few full-size aeroplanes have simple box-shaped fuselages and duplicating a rounded fuselage will add structural weight. This means more power is required to fly the model, and it will fly faster as a consequence. That in itself is not necessarily important, except that the faster the model flies the faster it will land, and thus the more liable it is to damage itself in a bad landing. What is important, however, is that the faster flying speed will make *stability requirements* more important.

There are answers to most of these problems, if not complete ones. The first, and most important, is to choose a full-size prototype which has proportions fairly close to semi-scale model requirements to start with, preferably with a simple

fuselage shape which can be duplicated in a simple model structure without adding excess weight. Above all, avoid the sleek, streamlined low-wing aeroplanes which may look attractive but will be hard to build, and even harder to get to fly without extensive modifications of proportions. To start with, some have little stability as full-size aeroplanes. The same outlines can be quite hopeless when applied to a free-flight model where automatic stability is essential for satisfactory flight.

Having settled on a suitable prototype, it is then a matter of compromise on such matters as dihedral and tail areas. To play safe, you increase these values. To retain true or very near scale outlines you retain the original proportions, or exaggerate them only slightly (so that appearance is largely unchanged). The model will have less stability than a normal free-flight model as a consequence, but it may have enough to be flown under good conditions, that is in calm weather. That is another basic rule. The lower the margin of stability in the *model* design, the more important it is to restrict flying to calm weather when there is less chance of a gust upsetting it and showing up the deficiencies in stability.

Another important thing is to avoid all excess weight, not just in the structure but in doping and finishing. Colour dopes, generously applied, may result in an excellent appearance, but can add a lot of weight. Model size and "permissible" maximum weight are closely related, and should follow closely figures typical for semi-scale models (Table X). It is then possible to get a satisfactory flying performance with moderate to low engine power, and with the flight much safer as a consequence.

An alternative solution to the lack of "model" stability inherent in full-size aeroplane outlines is to provide the model with a form of "automatic pilot" to apply correction automatically when needed. Devices of this type are usually based on a simple pendulum mounted in the fuselage and connected to the tail surface controls. If the pendulum is limited to swing in a fore and aft direction, control can only be applied to the elevators (Fig. 38). If freely pivoted, the pendulum can be linked to both elevators and rudder. Alternatively, the rudder only

TABLE IX. TYPICAL SIZES OF "DURATION" POWER MODELS

Model Span		30 in.	35 in.	40 in.	45 in.	50 in.	55 in.	60 in.
Engine Size	Diesel	0·5–0·8	0·8–1	1–1·5	1·5	2·5	3·5	—
	Glow	·049	·049–·09	·09	·09–·15	·15–·19	·19–·29	·29–·35

TABLE X. TYPICAL SIZES OF SEMI-SCALE SPORTS POWER MODELS

Model Span	15–22 in.	24–28 in.	28–32 in.	34–38 in.	40–44 in.	44–48 in.	48–54 in.	54–60 in.	60–72 in.	over 72 in.
Diesel (c.c.)	—	0·5	0·5	0·8	1	1·5	1·5–2·5	2–2·5	2·5	3·5
Glow (cu. in.)	·01–·02	·02	·049	·09	·09	·15	·19	·29	·29	·35
Max. Weight (ounces)	6	10	10	15	20	30	30–40	40	50	70
Max. Wing Loading (oz./100 sq. in.)	5	6	7	8	9	10	11	11	11	12

may be controlled by a simple pendulum mounted in a fore and aft direction, the rudder being the most powerful control in any case.

The principle involved is extremely simple. Consider pendulum rudder control first. If the model starts to slip or bank to one side the pendulum also swings to that same side applying *opposite* rudder movement to correct the departure from the original flight path. Similarly with pendulum elevator controls.

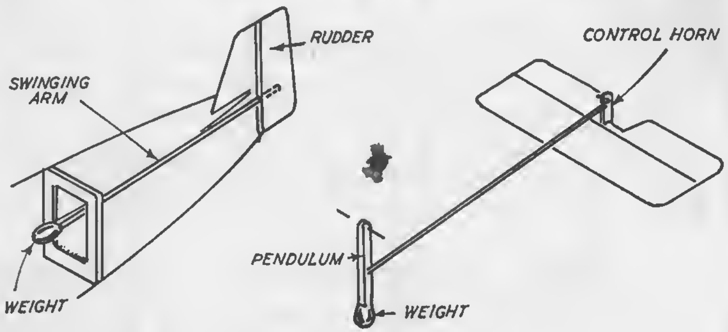


Fig. 38

If the model starts to climb excessively the pendulum swings backwards, applying down elevator to correct. If the model starts to dive the pendulum swings the other way to apply corrective up elevator.

In actual fact no such simple device as a pendulum can provide foolproof "automatic pilot" control. The pendulum will be affected by *acceleration* of the model as well as changes in altitude and under certain conditions can apply "corrective" control movements in the opposite way to that required. Nevertheless, in practice pendulum controls can give quite successful results and make it possible to achieve reasonably stable flight with models employing true-scale outline proportions. The flight is unlikely to be perfectly steady, but with a suitable design and position of pendulum and *limited* control movement, the delay in applying correction at times, and the tendency to overcorrect at others, may even make the flight more thrilling and realistic—especially, say, in the case of a scale World War I biplane. The necessity of limiting control movement is im-

portant, and in the case of the rudder a movement of two or three degrees only is the maximum which should be used, otherwise there is a distinct possibility of the pendulum "locking" the rudder with the model entering and remaining in a spiral dive.

Pendulum control may also be extended to ailerons as well as rudder and elevators, although with this more complex hook-up "auto-pilot" action is likely to be much more erratic. Such a system is not to be recommended until one has tried several models with simpler pendulum controls and appreciate their workings, and limitations. Pendulum controls are really another "compromise" solution—not a complete or even partially complete answer to stability problems with flying scale models. The only complete answer is *full* control of the model all the time it is in flight, which can be obtained only with control-line flying, or multi-channel radio control.

CHAPTER 7

JET MODELS

THE only practical—and acceptable—jet power unit so far developed for free-flight models is the "Jetex" solid fuel rocket available in a number of sizes giving from ½ ounce up to about 5 ounces thrust. Thrust duration is limited by the size of the charge which can be loaded into a relatively small volume and, typically, may range from about 5 to 10 seconds. The "Jetex" is, therefore, a limited duration power unit and so for maximum overall flight performance is best applied to "power-duration" type layouts, but of much smaller size and lighter weight to match the size and thrust of the "Jetex" unit. It can, of course, equally well be applied to other types of free-flight models, accepting that flight durations will be limited, and makes practical the small size *jet* scale model, as well as unorthodox layouts which are difficult to fly with engine or rubber-motor power because of engine torque. The "Jetex" provides power in the form of pure thrust, like a full-size jet engine, with a complete absence of torque.

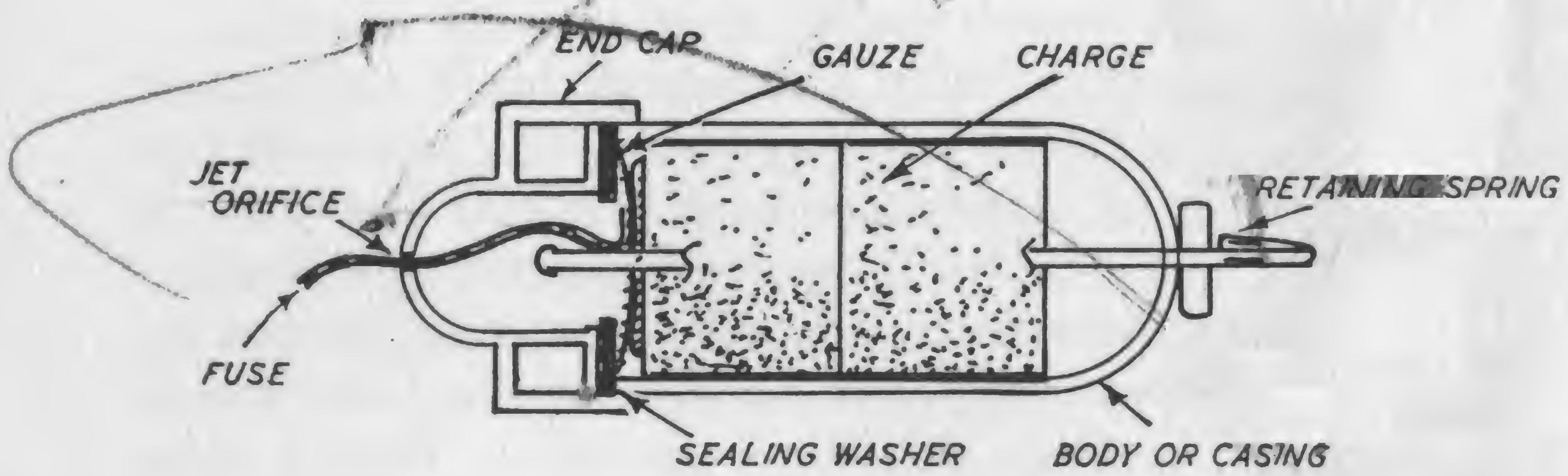


FIG. 39

A "Jetex" unit is shown in Fig. 39. The casing is of aluminium and fitted with an end cap held in place with springs or a spring clip. This is a safety measure to allow the end cap to lift off should the jet orifice be blocked in the end cap, preventing

gases escaping when the charge is ignited. The end cap normally seals on a gasket, which must be kept in good condition, or replaced if damaged, to prevent leakage and loss of thrust during normal firing.

The charge—a special rocket fuel—is ignited by a fuse held in contact with the end of the charge by a wire gauze, the free end of the fuse being taken out through the jet orifice so that it can be ignited from the outside. The fuse material is actually a

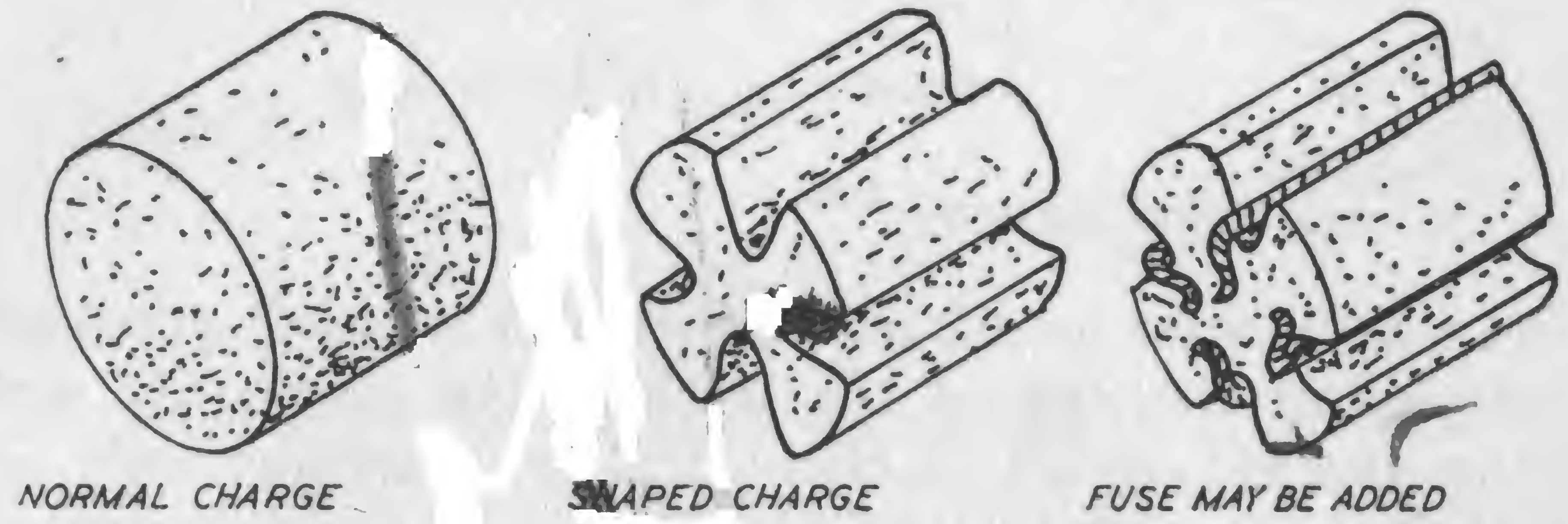


FIG. 40

chemical coating on a very thin wire and for maximum thrust the wire should be pulled free from the jet orifice as soon as the charge is ignited, or loaded in such a way that it will blow free and so not partially block the jet.

It is possible to obtain more thrust from a standard "Jetex" unit by "shaping" the charge, although this will also reduce the *duration* of the thrust. "Shaping" consists of cutting grooves in the charge, as shown in Fig. 40, to promote more rapid burning. Thrust may be roughly doubled (and duration halved) by laying additional lengths of fuse in the grooves so that the whole of the charge is ignited along its length simultaneously. Increasing the burning rate of the charge in this manner also increases the heat developed, which may be enough to melt the aluminium casing! Special heat-resistant cases are used in such cases.

Thrust can also be increased by combining the "Jetex" with an *augmenter tube* (Fig. 41). The tube has a bell-mouthed shape at the front end into which the rocket jet is directed, position of the bell-mouth relative to the jet being fairly critical for best results. The overall length of the tube can be extended by

plugging on additional straight tube lengths to suit a particular model layout.

Besides being a thrust booster, an augmenter tube is also useful for accommodating the "Jetex" inside the fuselage of, say, a scale jet model, enabling the "Jetex" to be placed at the

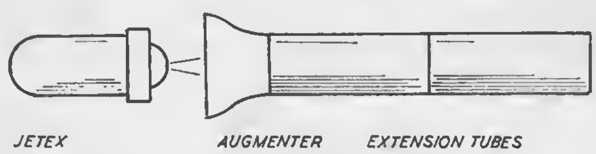


FIG. 41

balance point of the model, with the jet itself exhausting through a tailpipe at the end of the fuselage. An alternative and simpler method which is often used with smaller-scale jet models is to mount the "Jetex" in an open "trough" formed in the bottom of the fuselage—Fig. 42. This is not, of course, true scale but has the virtue of making it very easy to remove the "Jetex" for reloading.

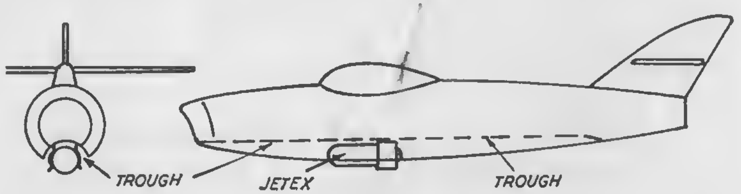


FIG. 42

Model proportions for stability are similar to those of other free-flight models, except that with the absence of torque wing dihedral can be kept to low values for scale models and tail surfaces can be smaller. Also, with a duration-type model, exaggerated pylon mounting of the wing is no longer necessary. It is better, in fact, to locate the thrust-line fairly close to the wing, a typical layout being shown in Fig. 43, with sizes, etc., summarized in Table XI.

One peculiarity of "Jetex" propulsion which affects both

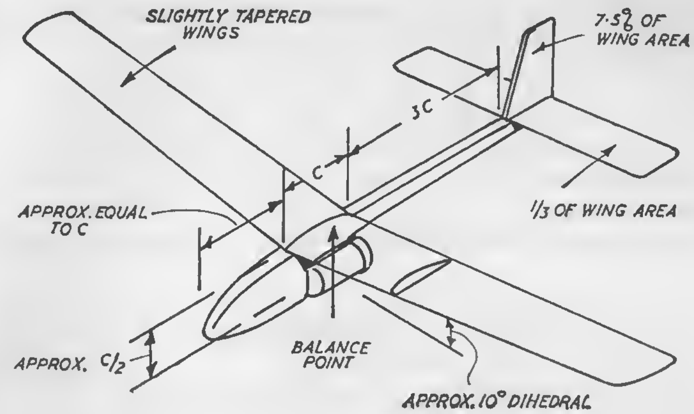


FIG. 43

design and trimming is that although the thrust is fairly constant after the initial build up, the *efficiency* of the jet engine and thus the power developed increases with increasing speed. In practice, this means that under "Jetex" power a conventional free-flight model will tend to accelerate throughout most of the power run, which will show up any faults in trimming or warps in construction in the form of instability, e.g. a slight turn to start with may end up as a steeply banked turn with the model losing height under power; or develop a moderate climb into a series of loops. Trimming a "Jetex" model, therefore, needs care, and particular attention must be paid to seeing that the

TABLE XI. TYPICAL "JETEX" MODEL SIZES

JETEX UNIT	NOMINAL THRUST (ounces)	MODEL SPAN (inches)	MODEL CHORD (inches)	WING AREA (sq. in.)	TOTAL MODEL WEIGHT (ounces)
Atom 35	$\frac{3}{8}$–$\frac{1}{2}$	10–12	$2\frac{1}{2}$	25–30	$\frac{1}{2}$–$\frac{3}{4}$
50	$\frac{3}{4}$	18	3	50	$\frac{3}{4}$–1
100	1–$1\frac{1}{4}$	24–30	4	100–150	1–$1\frac{1}{2}$
PAA-Loader	$1\frac{3}{4}$–2	24–36	$4\frac{1}{2}$	125–175	$1\frac{1}{2}$–$2\frac{1}{2}$
Scorpion	4	32–44	$5\frac{1}{2}$	180–260	8–12

"Jetex" unit is always mounted in exactly the same position in its clip, as any slight change in position can disturb the alignment of the jet thrust and upset trim. Otherwise "Jetex" flying is quite straightforward, with the cost a few pence per flight for the charges. Although this may seem a lot, this cost is actually less in overall figures than the cost of engine-powered flying.

The "Jetex" also lends itself well to unorthodox models

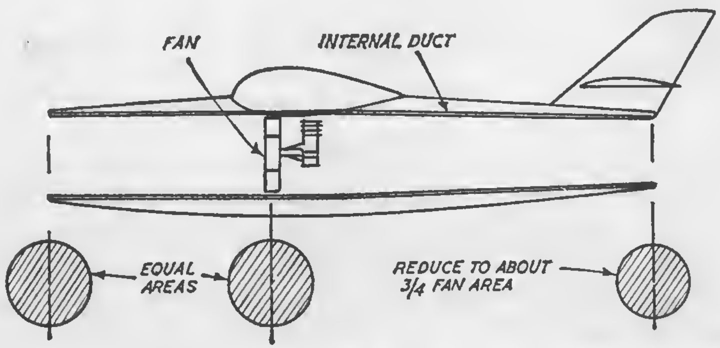


FIG. 44

which are not easy to power by other means, such as helicopters, deltas, etc. (see Chapter 8).

The main limitation is that the size of even the largest "Jetex" unit restricts maximum model size to about 44 in. span, whereas the most popular "Jetex" sizes ('35 and '50), restrict sizes to about 18 in. span. Also, of course, all "Jetex" units are capable of only a short power run, so flight durations are naturally limited. A "Jetex" unit is not suitable for a control-line model, for example, although it may be used for "sprint" or "speed" models for tethered indoor flying (see Chapter 15).

For larger "jet" models there is an alternative—ducted fan propulsion. Basically this comprises a hollow tube running throughout the length of the fuselage, in which is mounted a conventional diesel or glow engine fitted with a multi-bladed small-diameter fan or impeller (Fig. 44). This is not really true jet propulsion, the model being propelled by the slipstream

generated by the fan directed through the tube. It also tends to be relatively inefficient as a method of producing thrust, unless the fan is carefully made and closely fitted to the tube diameter. Tube shape is also important, some benefits being obtained by increasing the diameter forward of the fan and decreasing it aft of the fan to connect to a smaller diameter tailpipe. Again, however, unless these changes in diameter are correctly proportioned the result will be a loss of thrust, rather than an

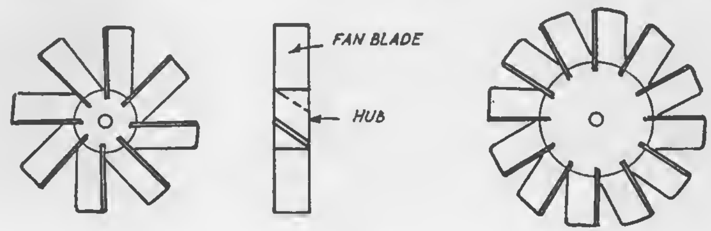


FIG. 45

improvement. A parallel "straight through" tube may, in fact, be the best proposition.

The faster the fan can be driven, the better the effect. A fast running speed will normally be ensured because the fan diameter is much smaller than a normal propeller fitting the same size of engine for free-flight thrust. However, the engine itself may be limited as regards the ultimate speed it can reach with a fan type load. Glow motors tend to be better than diesels in this respect.

The fact that the engine is mounted *inside* the fuselage (actually inside a tube in the fuselage) presents some problems, particularly as regards starting. The fan cannot be flipped over, so starting must be done by a cord wrapped round a light rim-type flywheel, or a pulley section incorporated on the fan. This means that the fuselage must have a hatch to give access to the engine, and it is necessary to have this hatch very close fitting where it breaks the tube section in order to avoid air leakage and loss of thrust when closed.

Being a form of jet propulsion, the ducted fan also has similar characteristics to "Jetex" in that its efficiency increases with speed. Such models, therefore, normally fly quite fast—

if they cannot fly fast enough the thrust developed will be insufficient to keep the model flying. They are thus not an easy type of model either to design or to build, but can be a most interesting and satisfying type of free-flight models when necessary details are worked out properly. Typical data regarding sizes, etc., are summarized in Tables XII and XIII as

TABLE XII. TYPICAL DUCTED FAN MODEL DATA

Engine Size	Model Span		Weight (ounces)	Wing Area (sq. in.)	Wing Loading (oz. sq. ft.)	R.P.M.	Fan Dia. (in.)
	Orthodox	Delta					
0·5–0·8 c.c.	24	20	7–10	100–110	9–10	10,000	3–3¼
1 c.c.	28	24	12–16	150–160	10–13	10,000	4
						13,000	3½
1·5 c.c.	32	26	16–22	190–200	12–14	10,000	4¼
						13,000	4
2·5 c.c.	35	28	22–28	230–250	13–18	10,000	4½
						15,000	4
0·29 cu. in.	44	32	30–40	300–330	14–20	10,000	5
						15,000	4¾
0·35 cu. in.	48	36	40–50	350–400	14–20	10,000	5
						15,000	4¾

TABLE XIII. TYPICAL FAN SIZES

	0·5–0·8 cc. 0·049 Glow	1 c.c. 0·09 Glow	1·5 c.c.	2·5 c.c.	3·5 c.c.	0·29 or 0·35 Glow
Diameter	3 in.	3½ in.	3¾–4¼ in.	4–4½ in.	4½ in.	4¾–5 in.
No. of Blades	9	12	12	12	12	12

a general guide to requirements. Suitable fan types are detailed in Fig. 45.

Ducted-fan models also have certain advantages, apart from being the only suitable form of power for larger free-flight jet models. Since engine and fan are mounted inside the fuselage they are protected against damage in hard landings, etc. Also no undercarriage is needed, so that semi-scale and scale jet models have all the realism of the full-size aircraft in flight with

undercarriage retracted. They are also a very interesting type for the serious modeller to develop.

There is another type of jet engine produced, known as a pulse jet and based on the same operating principle as the V1 or buzz-bomb power plant of World War II. This runs on straight petrol, can develop several pounds thrust for less than one pound in weight, and is capable of propelling models at speeds up to and exceeding 150 m.p.h.! Because of its noise, fire risk, and the potential hazard to the public and property of such fast-flying models, the use of pulse jets as a power unit for free-flight models is banned in this country. It may, however, be used for control-line flying, although again it is looked on with little favour by the authorities, largely because the noise may be heard over a distance of several miles and there is nothing that can be done to silence a pulse-jet.

CHAPTER 8

UNORTHODOX MODELS

SUMMARIZING the main characteristics of free-flight models described in earlier chapters: (i) all free-flight models need to have "automatic stability" built into the design; (ii) original designs usually fly better than semi-scale or scale models; and (iii) light construction is essential for good flying performance. These requirements lead to a general similarity between different *types* of models. Models which embody quite different shapes or proportions, or even different flying principles, are generally classified as *unorthodox* models. Again they can be completely original designs, or patterned on unorthodox full-size layouts. The latter are more usual since most of the "flyable" shapes have been tried as full-size designs, and many such shapes are quite well known.

The full-size helicopter is a typical example. It is not an easy type to reproduce as a flying model, however, since it is virtually impossible to duplicate the relatively complicated mechanism of the rotor hub on which the stability and performance of a full-size helicopter largely depends. Model helicopters thus merely employ the same basic principle of deriving lift from a rotating rotor, and from then on are purely "original" designs.

In the case of a rubber-driven helicopter the design becomes highly original or "unrealistic" since, in its basic form, it consists essentially of a long stick-type fuselage with a large propeller at one end, forming the rotor. To prevent the rubber motor rotating the fuselage faster than the rotor and thus wasting power, fins may be attached to the fuselage to restrict its rate of spinning (Fig. 47). Alternatively, a second rotor (large propeller) may be coupled to the other end of the rubber motor, rotating in the opposite direction to the first and thus having opposite pitch. Such models, very lightly built and

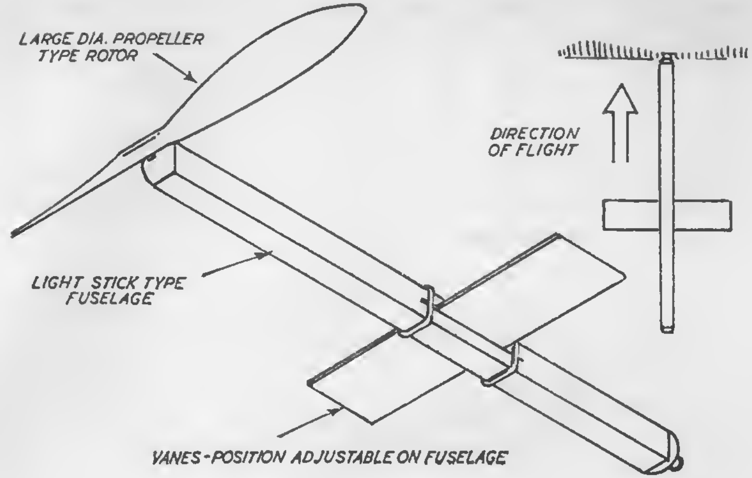


FIG. 46

with a long fuselage to accommodate a good length of rubber motor, may be capable of flights of 1–3 minutes duration. Stability is a problem, however, with fixed angle rotors, with a tendency for the model to fall to one side as it climbs and even turn right over and dive into the ground. Altering the position of the fixed vanes on the fuselage can often cure this.

With engine power a semi-scale layout can be adopted in which the fuselage unit merely becomes an appendage suspended from the rotor system. The rotor may be directly driven by an engine-driven airscrew mounted on an arm on the rotor system at right angles to the main rotor; or the rotors may be attached to the crankcase of the engine so that as the

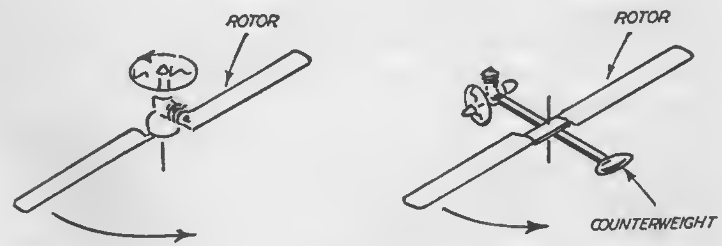


FIG. 47

engine drives its own propeller it also rotates in the opposite direction under torque reaction and so drives the rotors. Both schemes are shown in Fig. 47—and both can work quite well. The main requirement is a stable rotor system. A fixed angle rotor is not stable—it produces the effect described above for rubber-powered helicopters. Thus stability has to be provided by pivoting or hinging the rotor blades about the hub, allowing them to alter their angle of attack as they rotate.

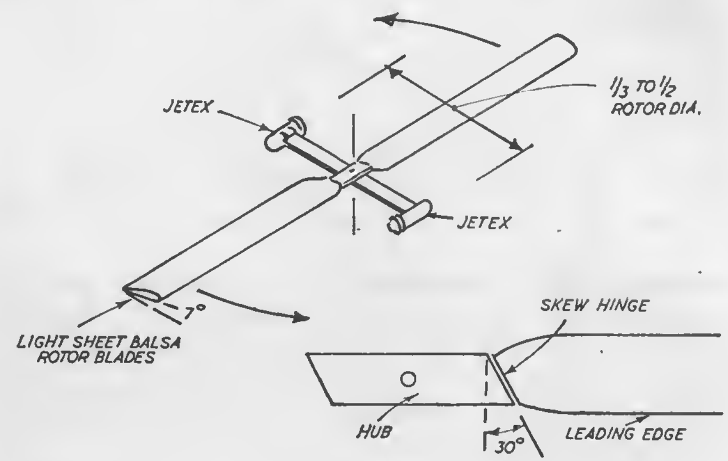


Fig. 48

The "Jetex" unit provides an even simpler method of powering a model helicopter rotor, using one or two "Jetex" motors mounted as shown in Fig. 48, and completely eliminates torque problems. Again, hinged or pivoted rotors must be used, otherwise the rotor system will not be capable of stable flight. The other advantage of a hinged rotor system (for both "Jetex" and engine power) is that when the power runs out the rotors will continue to *autorotate* in the same direction and thus give a safe descent.

Autorotation, where a rotor system is not power driven but rotates under the action of an airstream is the principle of *autogiro* lift (or helicopter descent, when the power is shut off). It is distinct from "windmilling" since the blades actually advance *into* the direction of the airstream. Windmilling pro-

TABLE XIV. DESIGN DATA FOR "JETEX" HELICOPTERS

Jetex	Rotor Dia. (inches)	Rotor Blade Area (sq. inches)	Skew Hinge Angle	Blade Incidence
50	22	18	30°	5°
100	30–34	40	30°	7°
150	36	55	30°	7°
Scorpion	60	150	30°	7°

duces a lot of drag with very little lift. Autorotation produces a reasonable amount of lift with fairly low drag. To fly successfully, therefore, a model *autogiro* must have a freewheeling rotor which will *autorotate* rather than windmill—something which is fairly difficult to achieve. The power in this case is provided by a conventional propeller on the front of the fuselage pulling the model forward (powered either by a rubber motor or small engine).

Normally this requires that the rotor blades be set at a negative angle (negative pitch) relative to the rotor shaft, with the rotor shaft itself inclined backwards slightly. The thrustline of

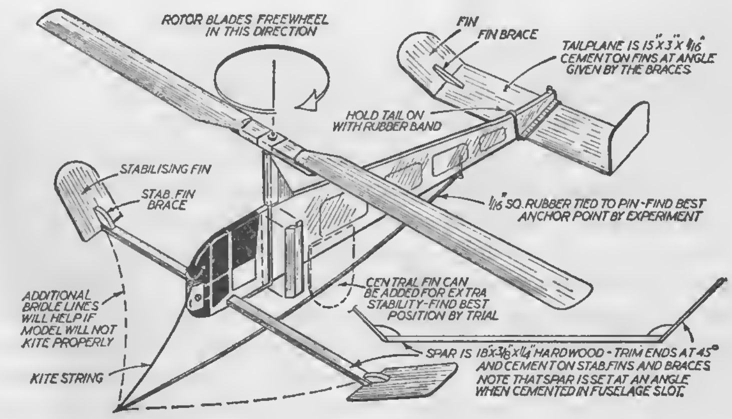


Fig. 49

the pulling propeller must be angled downwards to a considerable degree. Engine torque will tend to roll the model, and this may have to be dampened by fitting stub wings with sharply dihedralled tips. Design requirements, in fact, are quite tricky and have largely to be worked out on a "trial and error" basis. This type of model can be made to fly quite well, however, and represents a real challenge to the modeller who wants to produce a flying model which is quite different from all other types.

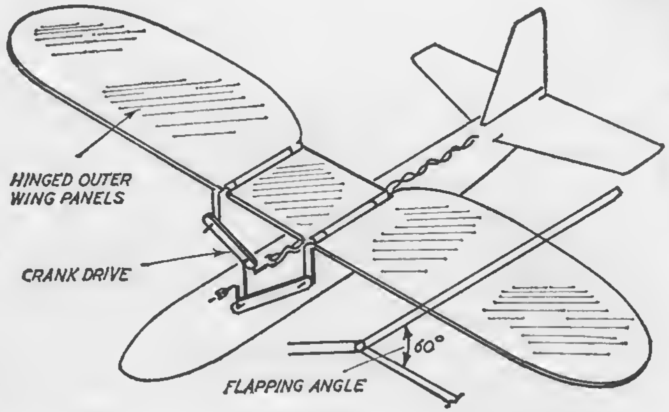


FIG. 50

Actually the autogiro *kite* is a simpler type to make, and usually more successful, than a powered autogiro (Fig. 49). The powered model can use a similar configuration, but the construction should be lighter—e.g. using a built-up box fuselage and built-up tissue covered rotors. Whatever form of power is used (rubber motor or engine), this should be mounted with a "down-thrust" angle of some 10 to 15 degrees.

Another quite tricky model is the *ornithopter* or "wing flapper." In this case propulsion is obtained by a flapping wing in a similar manner to bird flight. What works very effectively for birds, however, is extremely difficult to emulate in model flight and the best of ornithopter models only has "marginal" power of flight. The majority never have enough power to accomplish more than a prolonged glide. Again, however, it is a

type of unorthodox model which attracts the serious experimenter.

Practically all successful model ornithopters are rubber-powered, largely because the flapping rate of the wings needs to be kept fairly low (between one and two beats per second), which cannot be achieved by driving from a high-speed engine without heavy (and generally unreliable) gearing. With a rubber-powered model a simple crank mechanism can be used, connected by a link rod to pivoted outer panels of the wing (Fig. 50). A more or less conventional tail unit is added for

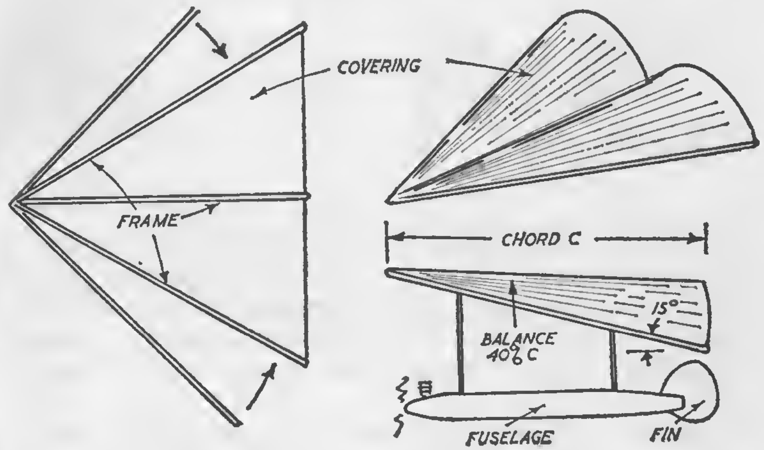


FIG. 51

stability, the fuselage normally being of elementary form to accommodate the rubber motor and carry the tail. Construction must be kept as light as possible and conventional rather than bird-wing shapes are most likely to prove successful—at least for the first models when design details are being worked out by "trial and error."

A far more promising layout in the unorthodox field is the *flex wing*—virtually a type of powered kite which has been produced as full-size flying machines. A basic model *flex wing* consists of nothing more than three stiff ribs or spars (e.g. aluminium tube or bamboo) assembled in arrowhead form and loosely covered with a light, non-porous flexible material such

as sheet polythene. The material should be slack enough to "balloon" evenly between the spars (Fig. 51). This can be most easily done by attaching the covering taut to the arrow-head frame and then bending the outer spars inwards an equal amount each, as shown in the diagram.

The model is then completed by suspending a conventional fuselage below the wing. This suspension should be rigid (e.g. wire braced) so that the wing is mounted at an angle of about 15 degrees to the fuselage and lined up accurately fore and aft

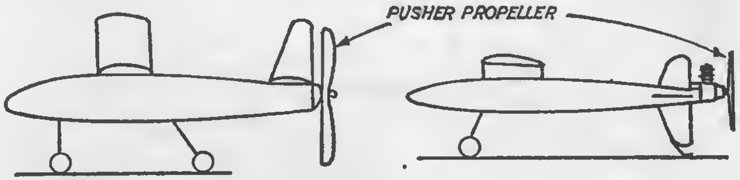


FIG. 52

with the wing centre spar. Correct balance point will then come about 40 per cent back from the front of the "arrowhead" with an effective wing sweep of about 50 degrees (farther back if the sweep angle is greater). The flex wing model can be powered by a rubber motor or a small engine, or can even be flown as a glider.

Many of the other unorthodox models are almost conventional by comparison. Thus the *pusher*, for example, is a more or less conventional flying model layout with the airscrew at the rear of the fuselage instead of the front (Fig. 52). Proportions are orthodox free-flight, except that the wing must be located farther aft or the fuselage nose lengthened to balance the weight of the rear propeller (and engine in the case of a power model). The undercarriage will also have to be relocated to protect the propeller in landing. Also, of course, the propeller must be a "pusher" type, carved with opposite pitch or rotating in the opposite direction to convention. A "pusher" propeller is required on engines which normally rotate only in one direction (anti-clockwise when viewed from the front or propeller end). A conventional propeller can be used on a rubber-powered model since this can be driven in the opposite

direction to normal simply by winding the motor up the other way.

The *canard* or tail-first model also makes an interesting project, and is usually employed with a pusher propeller (although canards also make interesting gliders). Typical design proportions are shown in Fig. 53. It is a characteristic of all canards that the balance point comes in front of the main wings,

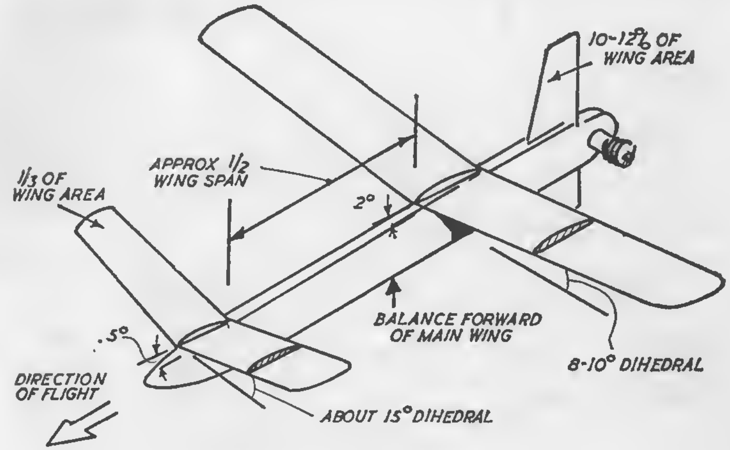


FIG. 53

with the leading plane always set at a greater rigging angle (angle of incidence) than the main wings. Properly proportioned, the canard arrangement is quite stable and efficient and can even make a good "duration" design for rubber-powered models.

Tail-less models have always been popular, although they present considerable stability problems. For greatest efficiency the wing needs to be of fairly high aspect ratio with a good span, when stability is provided by sweepback and reflexing or decreasing the angle of incidence towards the tips. Efficiency suffers because reflexing reduces the overall lift, also rather more stable aerofoils (and thus less efficient lifting sections) normally have to be employed. Stability provided by reflexing and sweepback is also far less than that given by an orthodox

tailplane. Thus "duration" performance cannot compare with an orthodox layout.

The high-aspect-ratio tail-less layout is the logical choice for a glider or rubber-powered model. With engine power (and more especially "Jetex") the wing planform can be rendered as a true delta. This will considerably improve the stability, but still further reduce the efficiency or amount of lift generated

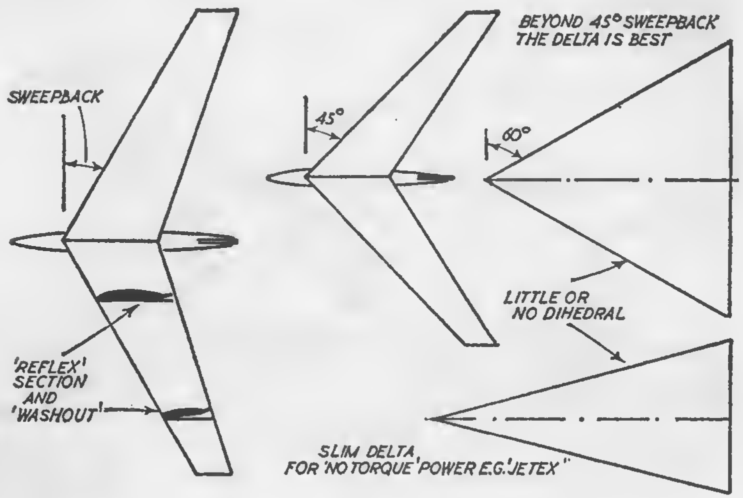


FIG. 54

by a given wing area. Torque becomes a problem if too powerful an engine is fitted, so the delta is really best suited to a low-powered sports model. Increasing the span of the delta—i.e. using a broader triangular planform—is no answer since whilst this may improve lifting efficiency it will also decrease stability.

An alternative method of approach is the purely circular wing planform or flying saucer (Fig. 55). Strangely enough this makes an excellent free-flight model with small engine power (although not suited to rubber power), with relatively few stability problems. More or less conventional wing sections can be used, but not undercambered aerofoils, with a balance point between one-third and one-half the chord back from the

leading edge. The engine is most conveniently carried on a short fuselage or nacelle extending from the front of the circular wing, with directional stability provided by a fin of suitable size near the back of the wing.

Saucers, deltas, and to a less extent canards, also make suitable control-line models, the tail-less designs in particular being highly aerobatic with a hinged elevator at the wing trailing edge. The autogiro is another possible control-line type.

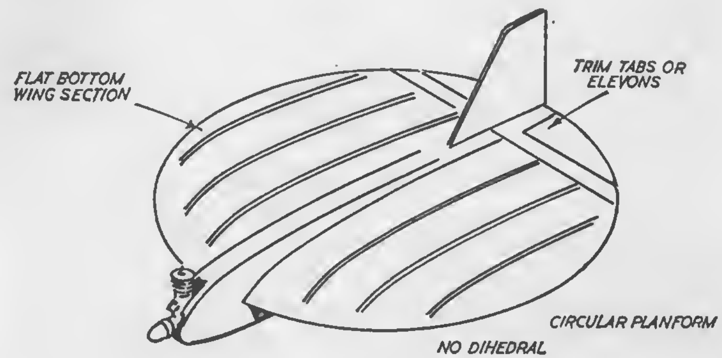


FIG. 55

Although not, perhaps, "unorthodox" models in the same sense as the models previously described in this chapter, electric-powered models do come into this category because of their comparative novelty. Electric motors are not normally suitable for model aircraft power units because of their low power/weight ratio, and also, because they have to carry additional weight in the form of batteries. However, small lightweight motors powered by very light batteries have been used successfully for free-flight models. The chief requirements are that the model must be extremely lightly constructed (usually on rubber "duration" lines), with the motor driving a large-diameter propeller via a high reduction gear ratio. This gives a better performance than the same motor driving a small-diameter fast-revving propeller direct and also reduces battery consumption.

Merely adapting a conventional rubber model to electric

motor power will not produce successful results. The design requirements are highly specialized and the power available will, in any case, be marginal. The electric-powered free-flight model is, therefore, essentially restricted to still-air flying. With an efficient low-consumption motor battery power can be provided by pen cells (preferably the high-energy type) with a motor running time of up to 10 minutes or more from a single set of batteries. It usually becomes necessary to limit the motor run by a cut-off switch operated like a dethermalizer (see Chapter 11). With smaller models the new ultra-lightweight water-energized batteries may be employed. These weigh something less than 1/10th ounce each and are capable of giving 1.4 volts per cell, once activated, for a matter of up to one minute. After that the cell is exhausted and must be thrown away.

Successful designs for unorthodox models are almost always evolved on a "cut and try" basis, often through a whole series of similar models, some successful and others not. The best starting point is to build from, or base an original design on, a plan of a successful model of the same type. Lacking mass appeal, few unorthodox models are produced as kits, but plans are readily available of almost any type, many of which may be record-breaking of record-holding models in their class. The chief sources of such plans in this country are—

Aeromodeller Plans Service, 38 Clarendon Road, Watford.
Model Aircraft Plans, 19–20 Noel Street, London, W.1.

CHAPTER 9

CONSTRUCTION

Built-up construction is favoured for the majority of small to medium-size models, or for all components on larger models where it is necessary or desirable to build down to minimum weights. Regardless of the component—wings, tail, or fuselage —the basic framework is always assembled flat over a full-size drawing or plan, spars, etc., being pinned in position over the plan with other parts cemented in place—again using pins to hold in position if necessary. The framework is then left in position until the cement has quite set.

The building board used must be flat and true for accurate construction. The plan is laid over the board and, to protect the surface, can be covered by a sheet of waxed paper or a candle rubbed over the plan surface to prevent cement sticking to it. Assembly of different components then follows a definite pattern and can be best dealt with under separate headings.

Fuselage Construction

In the case of a simple built-up box fuselage the two sides are built flat as separate frames and subsequently joined with formers and/or spacers. The basic stages involved are shown in Fig. 56, which can be studied in conjunction with the following notes.

The four main spar members or *longerons* should be selected to be as near equivalent as possible in grade. This is important to minimize the risk of the fuselage "springing" out of shape when finally assembled. To ensure that both side frames are identical it is also best to build them one on top of the other directly on the plan. This is also the quickest method.

The longerons are first pinned out in position accurately over the plan. Spacers are then cut accurately to length, in pairs,

and cemented in place. Cement in place one station at a time rather than cut two complete sets of spacers and then cement in place. Insertion of the spacers may "spring" the outline slightly, so by measuring off spacer lengths one station at a time, and fitting, you will get the most accurate assembly.

After completing the frames they should be left pinned down for several hours to ensure that the cement has completely set.

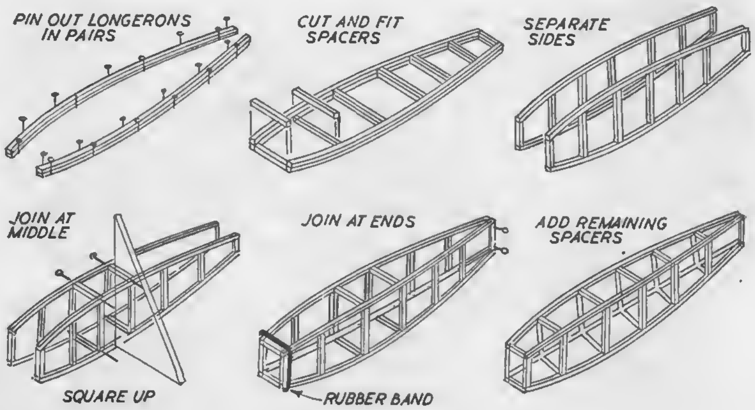


FIG. 56

Then remove all pins and lift the frames off the plan. They will be stuck together, so separate carefully by running a knife between them, taking care not to cut into the wood.

Joining of the two sides should always start at the middle or widest section of the fuselage. Cut the spacers to required length (measured off the top view of the fuselage), or use formers, as appropriate. Sides and spacers can then be cemented and pinned together if the longeron size is $\frac{1}{8}$ in. square or larger; otherwise hold the assembly with two rubber bands. Block up square (as regards cross section) and true (as regards alignment over the plan view) and leave to set. It is very important to get the fuselage assembly true at this stage.

The next stage consists of joining the tail ends of the sides (usually these are cemented together); and the front (with spacers). Use pins again to hold in position, and once more align over the plan view. When the cement has set, the re-

maining spacers can be cut and fitted to complete the basic framework. Again cut the spacers in pairs (top and bottom) and work one station at a time. Check the fuselage assembly for truth and squareness and allow to set.

It then only remains to add the detail parts, which may be specified, such as a nose former facing, anchorage plates for dowels, etc., bind the undercarriage in position (where applicable) and so on. On some models "fill-in" sheeting may be called for, which has to be cut accurately to size and cemented

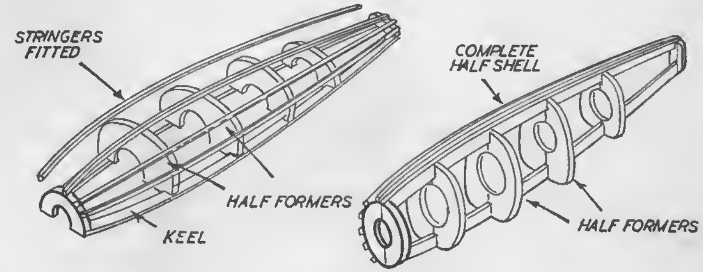


FIG. 57

in place. Complete all the fuselage details at this stage and then clean off and sand down lightly ready for covering.

There are, of course, variations on this type of construction, but the same basic technique usually applies. For example, formers cut from sheet balsa or even ply may largely replace spacers. This will, in fact, make it easicr to get the assembly square, although it usually increases the weight of the fuselage. In some cases, where the fuselage section is rounded, a complete half shell may be built flat over the plan, comprising backbone or keel members to which are cemented formers, with stringers then added—Fig. 57. This assembly is removed when set and the other half of the shell built directly on to it. In other cases a basic frame known as a crutch may be assembled over the *plan* view rather than the side view, with formers and stringers then added to complete the whole of the top of the fuselage whilst the crutch frame is still pinned down to the plan. The bottom fuselage construction is then added after the main assembly is removed from the plan.

Wing Construction

Simple wing construction is shown step-by-step in Fig. 58. Either the complete wing is built as one flat panel in the case of small models, or each half wing built as a flat panel. Leading and trailing edges and the mainspar(s) are pinned down directly over the plan and the ribs then cut and cemented in place. If the wing tips are also built up, these are also cemented in place at this stage. Alternatively, the wing tips may be carved from light block balsa, added after completing the main

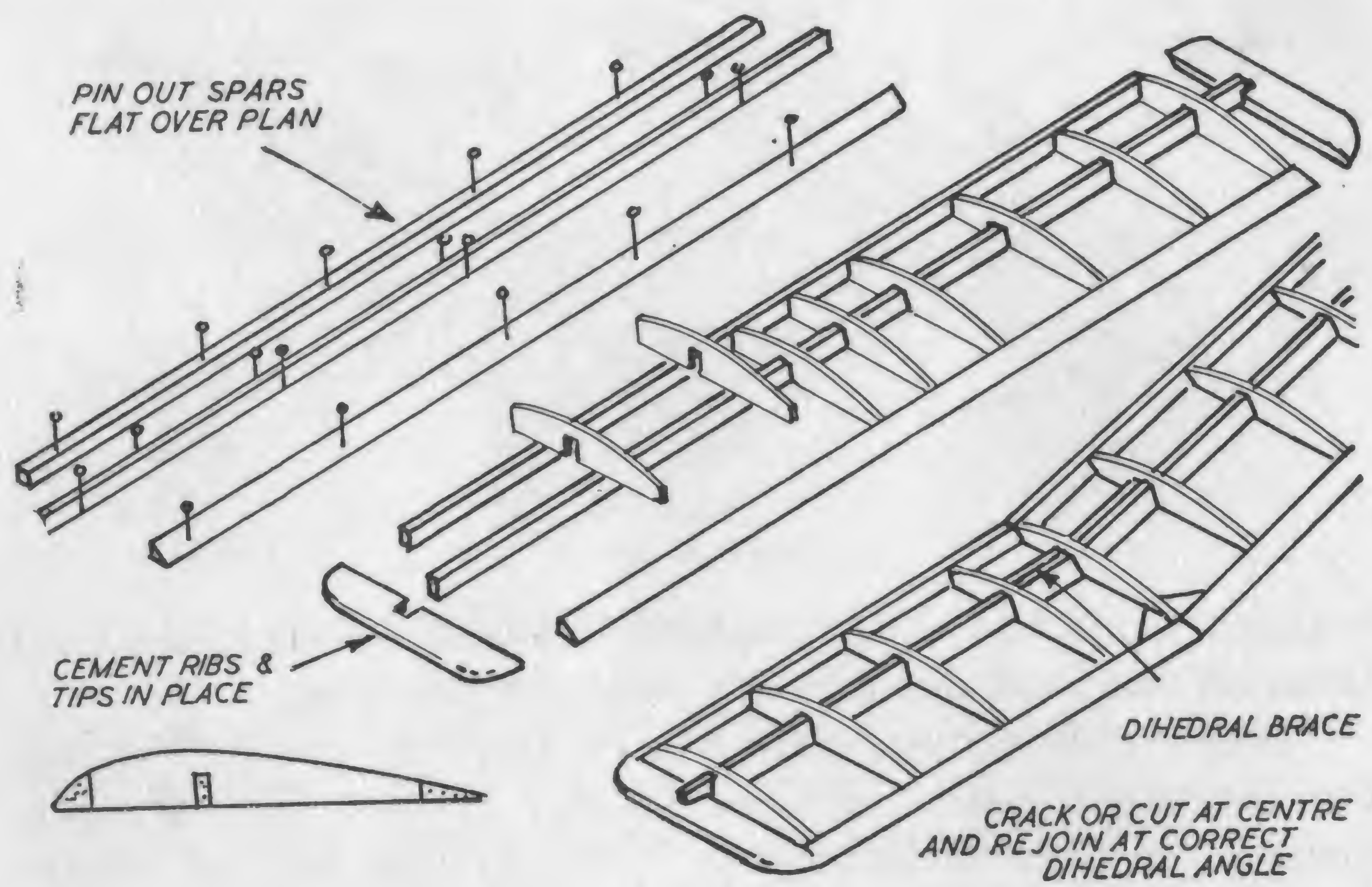


Fig. 58

wing assembly. Spars which slot into the top of the ribs are added after the ribs are cemented in place.

To form the dihedral a one-piece wing panel is notched at the dihedral joint, one panel supported so that the tip has the required amount of dihedral (tip rise) and dihedral braces added to strengthen the joint. In the case of two-panel wings the spar ends are carefully angled for a neat fit and the wing panels joined at the correct angle with dihedral braces and well-cemented joints. Gussets are also usually added to strengthen the joint at the leading and trailing edges. Once again one wing panel is left pinned down and the other blocked up so that the

tip is at the required tip-rise measurement, this being *twice* the tip-rise value for dihedral expressed at *one* wing tip.

The same principle applies when forming a polyhedral joint in a wing panel. The main thing is to keep one panel (or part panel) pinned down and block the other up accurately whilst the joint is completed and allowed to set. Blocks used to prop up the second panel must be at right angles to the leading and

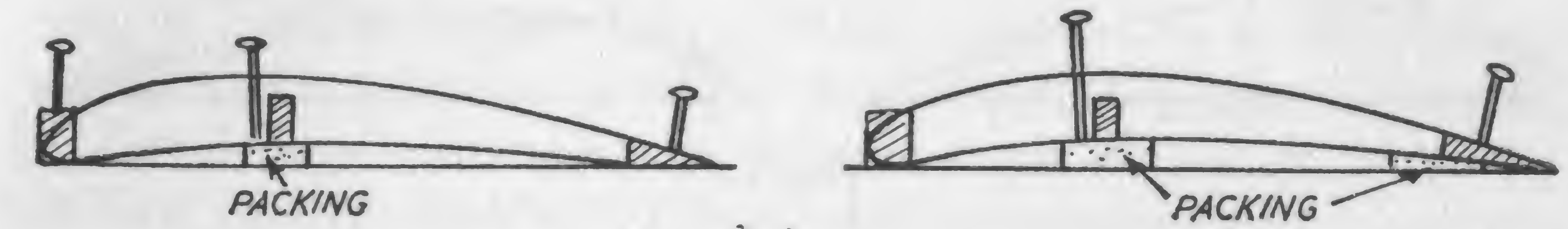


Fig. 59

trailing edge (or mainspar). If slewed they will cant the panel slightly and alter its angle of incidence.

Certain complications arise in the case of "duration" model wings where the section is usually undercambered. To make sure that the spars line up with the aerofoil section it may be necessary to block up both the mainspar and the front of the trailing edge when pinning these members down initially over the plan (Fig. 59). Similar considerations also apply when building a symmetrical-section wing (such as used on control-line models and some radio-control models). Here it becomes

Fig. 60

necessary to block up both the leading and trailing edge (Fig. 60). If a single spar is used running through the centre of the ribs, the ribs must be assembled on to this spar and the whole lot then positioned over the leading and trailing edge pinned down to the plan. Sometimes this is avoided by cutting symmetrical ribs in two parts so that the mainspar can be pinned down on to the plan for accurate alignment, the "missing" part of the rib being added later after the main assembly has been completed and removed from the plan.

Accurate alignment of ribs is helped by notching the leading and trailing edges so that the rib ends actually locate in these notches. This calls for an extra length of rib—thus notched assembly cannot be applied to a kit model which does not provide for it and where the ribs are already die-cut. Also mainspars should *never* be notched to assist alignment as this

Fig. 61

will weaken the spars unduly. The weakening effect on leading and trailing edges is negligible; but where notches are employed they should always be cut with a flat file of the same thickness as the rib, not with a knife blade.

On larger models a slightly different form of construction may apply. To save weight, the trailing edge may be built up of two pieces of sheet balsa, rather than a triangular section of solid balsa. Also the leading edge of the wing may be sheet covered (Fig. 61). Where this applies, as much sheet covering as possible should be fitted and cemented in place with the basic wing framework still pinned down flat on to the building

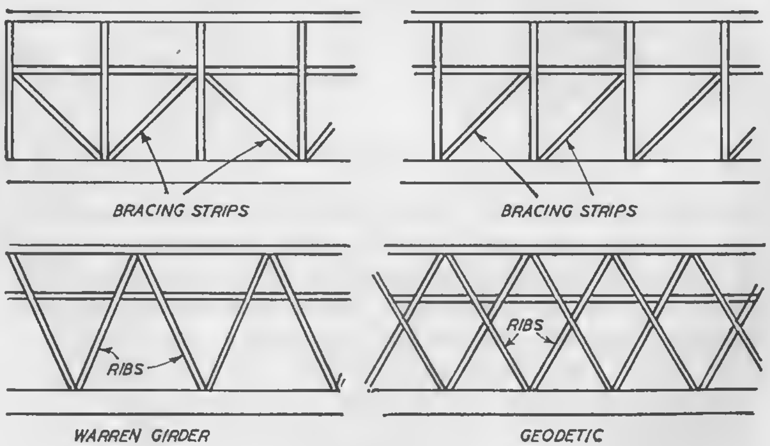


Fig. 62

board. This will eliminate the risk of warps being accidentally worked into the wing whilst applying the sheeting. Wing panels are joined in the same manner as before, but extra care is needed to shape the ends of the sheet accurately for the neatest possible joint line at dihedral breaks.

Some wing designs may employ additional diagonal bracing to provide an "anti-warp" structure—see Fig. 62. Basically, this additional bracing simply increases the rigidity of the wing as regards twisting loads, such as those imposed by the tautening of the covering. It is imperative that any such diagonal bracing be fitted *before* the wing panel has been removed from the building board. If added later it will almost certainly push the wing out of shape and add a permanent "built-in" warp. Other wing designs may incorporate anti-warp features in the arrangement of the ribs, e.g. "W"-alignment instead of straight fore and aft, or crossing in "X" form (known as geodetic).

Tailplane Construction

Assembly of a built-up tailplane is basically the same as that of a wing, with the complete frame built as one flat panel. Tailplanes are not usually given any dihedral angle and so the question of cutting and making a dihedral joint does not arise.

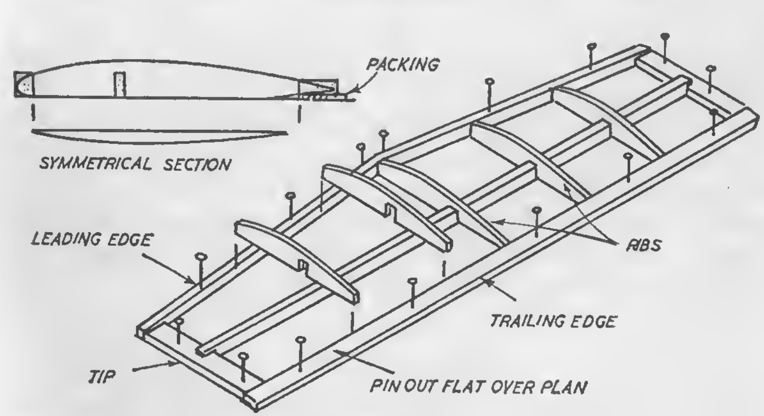


Fig. 63

Spar and rib arrangement is usually similar to that of the wing, so exactly the same considerations apply. Tailplane spar sizes will be smaller and lighter, however, so particular care may be needed to ensure a warp-free structure. Symmetrical tailplane sections set a problem in this respect and are generally best built with a "split" rib section (Fig. 63).

Shaping Leading and Trailing Edges

Leading and trailing edges are normally shaped from solid balsa spars. These spars may be pre-shaped—e.g. supplied or bought as leading and trailing edge sections, respectively—or individually shaped from square or rectangular strip balsa. In the latter case it is always best to shape these sections *before* pinning in place over the building board rather than carving and sanding to a matching shape after the frame has been completed. This is because shaping, especially on the trailing edge, will tend to *warp* the strip. Thus if a wing is built with a rectangular section trailing edge which is subsequently carved and sanded down to a matching triangular shape after completing the wing or tailplane framework it will have a natural tendency to develop an upward curl. If the structure is not rigid enough to withstand this, it will simply mean that the wing frame will warp under the locked in stresses of the trailing edge tending to make this member bow upwards. This may not be very significant or even important on a sports model or a fairly ruggedly built wing, but it can be important on a lightweight duration-model wing.

A certain amount of final shaping will probably be necessary in any case after the wing frame has been removed from the building board. If the trailing edge has to be sanded to any extent, and the structure itself is a lightweight one, this can be compensated by sanding the underside of the section lightly to pull out the "bow" which may be induced.

Fins

The fin is basically a simple structure which should not present any particular difficulties, although every endeavour

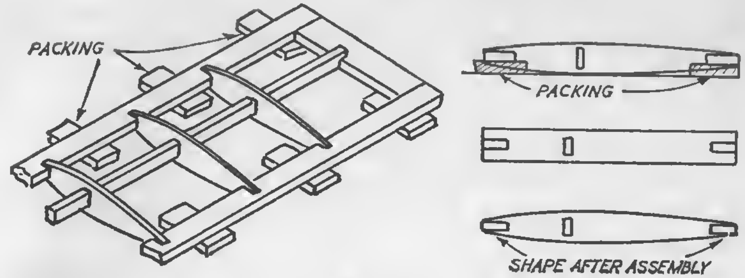


Fig. 64

must be made to avoid warps since this can lead to a lot of trimming troubles on the completed model. A flat-section fin is the simplest to make, but the one most prone to warping when tisue covered, especially if covered on one side only as is often recommended with small models. It is always best, in fact, to cover any fin on *both* sides, and strictly necessary if the section is "streamlined."

A fairly straightforward method of getting accurate assembly in the latter case is to block up leading and trailing edges equally, as shown in Fig. 64. The ribs can then be rectangular strips which just rest on the plan surface, making for good accuracy of alignment; or they can be cut to symmetrical section ready for assembly. In the former case the symmetrical section is formed by sanding away the ribs after the frame has been built.

Fins cut from light sheet balsa are quite suitable for glider and power models (although rather too heavy for lightweight rubber models). The fact that they are solid does not mean

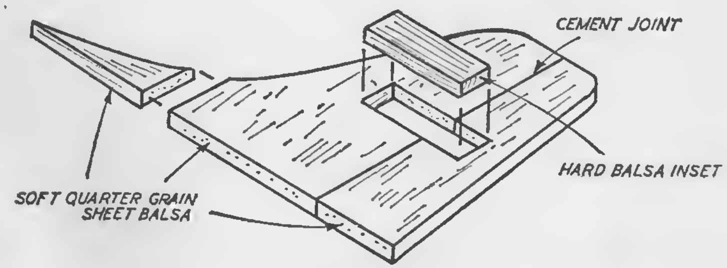


Fig. 65

that they will be warp-free, however. In fact, it is generally better to inset a strip of harder grade balsa with the grain at right angles to the main sheet to provide anti-warp properties—see Fig. 65. This method of inserting a "key" piece is also particularly useful as reinforcement when the fin is of such a size that it has to be cut from two pieces of sheet cemented together, the key then being equally disposed on either side of the joint line.

With commercial model aircraft designs—kits or plans—building instructions are usually specific, especially for parts which differ from conventional practice. Where no such instructions are given, assembly will normally follow on the lines detailed in this chapter.

TABLE XV. SUMMARY OF MATERIAL SIZES, etc. FOR ALL TYPES OF MODELS

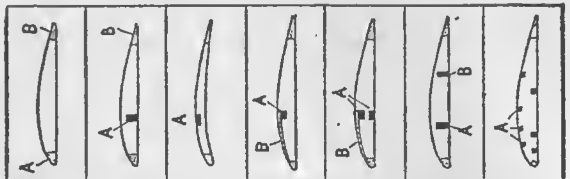
TAILPLANE

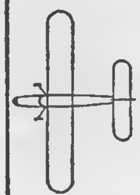
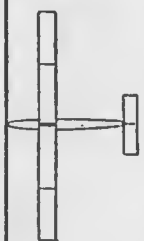
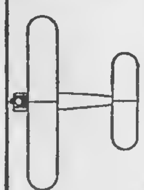
NOTES:
S-SHEET COVERING
R-RIB THICKNESS
N.R-NOT RECOMMENDED
S.R-SPECIALLY "
N.S-NOT SUITABLE

RUBBER ALL TYPES	SMALL	O.K. R 1/20	O.K. R 1/20	O.K R 1/20	N.R	O.K R 1/20	N.R.	N.R	N.R	N.R	N.R
	MEDIUM	O.K R 1/16	O.K R 1/16	O.K R 1/16	N.R	O.K R 1/16	N.R	N.R	N.R	O.K A 1/16°	N.S
	LARGE	N.S	N.R	O.K R 1/16	O.K S 1/32	SR R 1/16	O.K NO'S'	O.K	O.K R 1/16	O.K A 1/16°	N.S
	WAKEFIELD	N.S	N.R	O.K R 1/32	O.K S 1/32	SR R 1/32	O.K S 1/32	O.K	O.K R 1/32	O.K A 1/16°	N.S
GLIDERS ALL TYPES	SMALL	O.K R 1/20	O.K R 1/20	O.K R 1/20	N.R	O.K R 1/20	N.R	N.R	N.R	N.R	N.R
	MEDIUM	O.K R 1/16	O.K R 1/16	O.K R 1/16	N.R	O.K R 1/16	N.R	N.R	N.R	O.K A 1/16°	N.S
	LARGE	N.S	N.R	O.K R 1/16	O.K S 1/32	O.K R 1/16	SP S 1/32	O.K	O.K	O.K A 1/16°	N.S
	A-2	N.S	N.R	O.K R 1/16	O.K S 1/32	SR R 1/16	SR S 1/32	O.K	O.K	O.K A 1/16°	N.S
F/F POWER	SMALL	N.R	O.K R 1/16	O.K R 1/16	O.K	O.K R 1/16	N.R	N.R	N.R	O.K A 1/16°	N.S
	MEDIUM	N.S	N.R	O.K R 1/16	SR S 1/32	SR R 1/16	O.K NO'S'	O.K R 1/16	O.K	O.K A 1/16°	N.S
	LARGE	N.S	N.R	O.K R 3/32	SP S 1/16	SP R 1/16	SR NO'S'	O.K R 3/32	O.K	O.K A 3/32°	N.S
RADIO CONTROL	SMALL	N.R	O.K R 3/16°	O.K R 1/16	O.K S 1/32	O.K R 1/16	N.R	O.K R 1/16	O.K R 1/16	O.K A 1/16°	N.S
	MEDIUM	N.S	N.R	O.K R 1/16	O.K S 1/20	O.K R 1/16	N.R	O.K R 1/16	O.K R 1/16	O.K A 3/32	N.S
	LARGE	N.S	N.R	O.K R 3/32	O.K S 1/16	O.K R 3/32	N.R	O.K R 3/32	O.K R 3/32	N.R	N.S
C/L ALL TYPES	SMALL	N.R	O.K	O.K	N.R	N.R	N.S	N.S	N.S	N.S	SR T 3/32
	LARGE	N.R	O.K	O.K	N.R	N.R	N.R	N.S	N.S	N.S	SR T 1/8-3/16

WINGS

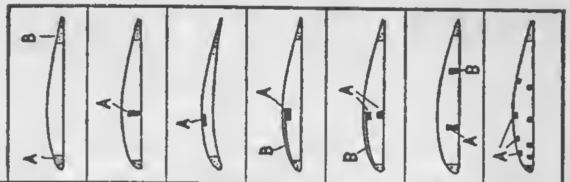
NOTES:
N.R NOT RECOMMENDED
H-HARDWOOD

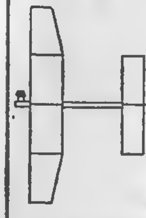
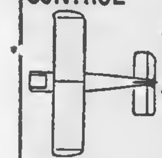
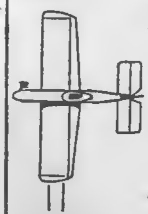
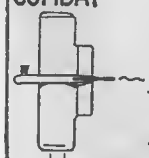


	SPAN SIZE							
RUBBER 	UP TO 20"	A 3/8x5/16 B 1/2 x 1/8	A 5/16x3/32 B 3/8x3/32	N.R	N.R	N.R	N.R	N.R
	20"-26"	A 3/8 SQ. B 1/2x3/16	A 3/8x3/32 B 3/8x1/2	N.R	N.R	N.R	N.R	N.R
	24"-30"	A 1/2x3/8 B 3/4x1/4	A 3/8x1/8 B 1/2x1/8	N.R	N.R	N.R	A 3/16x3/32 B 1/4x3/32	A 1/16 SQ
	30"-36"	A 5/8x1/2 B 3/4x3/16	A 3/8x1/8 B 1/2x1/8	N.R	A 1/8 SQ. B 1/32	A 3/32 SQ B 1/32	A 3/8x3/32 B 1/4 x 3/32	A 1/16 SQ.
	36"-42"	N.R	A 3/8x3/16 B 1/2 x 3/16	N.R	A 3/16x3/32 B 1/32	A 1/8 SQ B 1/32	A 3/8x1/8 B 1/4x1/8	A 1/16 SQ.
	WAKEFIELD	N.R	N.R	A 3/16x1/16 H	A 1/4x1/8 B 1/32	A 1/8 SQ B 1/32	A 3/8x1/8 B 3/8x1/8	A 1/16 SQ.
GLIDER 	UP TO 20"	A 3/8x5/16 B 1/2x 1/8	A 5/16x3/32 B 3/8x3/32	N.R	N.R	N.R	N.R	N.R
	20"-24"	A 3/8 SQ. B 1/2x3/16	A 3/8x3/32 B 3/8x1/8	N.R	N.R	N.R	A 1/4x3/32 B 1/4 x 3/32	N.R
	24"-30"	N.R	A 1/2x 1/8 B 1/2x1/8	A 1/4x1/8	A 1/8x1/16 B 1/32	A 1/8x1/16 B NO	A 3/8x3/32 B 1/4x3/32	A 1/16 SQ.
	30"-36"	N.R	A 1/2x1/8 B 1/2x3/16	A 3/16x1/16 H	A 1/8x3/32 B 1/32	A 1/8x3/32 B 1/32	A 1/2x1/8 B 3/8x3/32	A 1/16 SQ
	36"-48"	N.R	N.R	A 1/4x3/32 H	A 3/16x1/8 B 1/32	A 3/16x3/32 B 1/32	A 3/8x3/16 B 3/8x1/8	N.R
	48"-60"	N.R	N.R	A 3/8x1/8 H	A 3/16x3/32 H B 1/20	A 3/16 SQ B 1/20	N.R	N.R
F/F SPORTS 	UNDER 30"	A 1/2x3/8 B 3/4x1/4	A 1/2x1/8 B 1/2x1/8	N.R	A 1/4x3/32 B 1/32	N.R	A 1/2x3/16 B 1/2x1/8	N.R
	30"-36"	N.R	A 1/2x1/8 B 3/4x3/16	N.R	A 3/8x3/32 B 1/16	A 3/32 SQ B 1/20	A 1/2x3/16 B 3/8x3/32	N.R
	36"-40"	N.R	A 1/2x3/16 B 3/4x1/4	N.R	A 3/8x3/32 B 1/16	A 1/8 SQ B 1/20	A 1/2x1/4 B 3/8x1/8	N.R
	40"-48"	N.R	A 1/2x1/4 B 1 x 1/4	N.R	A 3/8x1/4 B 1/16	A 3/16 SQ B 1/16	A 1/2x1/4 B 3/8x3/16	N.R
	48"-60"	N.R	N.R	N.R	A 1/2x3/16 B 1/16	A 3/16 SQ B 1/16	A 1/2x1/4 B 3/8x1/4	N.R
	60"-72"	N.R	N.R	N.R	N.R	A 1/4 SQ B 1/16	A 1/2x1/4 B 1/2x1/4	N.R

WINGS

NOTE:
N.R NOT RECOMMENDED



F/F DURATION 	UP TO 30"	A 3/8x1/4 B 1/2x1/8	A 3/8x1/8	A 3/16x3/32	A 3/16 3/32 B 1/32	N.R	A 3/8x3/32 B 1/4x1/8	A 1/16 SQ
	30"-36"	N.R	A 3/8x3/16	A 1/4x1/8	A 1/4 x 3/32 B 1/20	A 1/8 SQ B 1/20	A 3/8x3/16 B 1/4x3/16	A 3/32 SQ
	36"-40"	N.R	A 1/2x3/16	N.R	A 3/8x1/8 B 1/16	A 1/8 SQ B 1/20	A 3/8x1/4 B 3/8x1/8	N.R
	40"-48"	N.R	N.R	N.R	A 1/2x3/16 B 1/16	A 3/16 SQ B 1/16	A 1/2x1/4 B 3/8x3/16	N.R
	48"-60"	N.R	N.R	N.R	A 1/2x1/4 B 1/16	A 1/4 SQ B 1/16	A 1/2x1/4 B 3/8x1/4	N.R
RADIO CONTROL 	30"-40"	N.R	A 1/2 1/4	N.R	A 3/8x3/16 B 1/16	A 1/8 SQ B 1/16	A 1/2x1/4 B 3/8x1/8	N.R
	40"-48"	N.R	N.R	N.R	A 1/2 x 1/4 B 1/16	A 3/16 SQ B 1/16	A 1/2x1/4 B 3/8x3/16	N.R
	48"-60"	N.R	N.R	N.R	N.R	A 1/4 SQ B 1/16	A 1/2x1/4 B 1/2x1/4	N.R
	60"-72"	N.R	N.R	N.R	N.R	A 1/4 SQ B 1/16	A 1/2x1/4 B 1/2x1/4	N.R
C/L STUNT 	20"-24"	A 3/8 SQ A 3/4 x 1/4	B 3/8x3/16	N.R	N.R	N.R	N.R	N.R
	24"-30"	A 1/2 SQ B 1x3/8	A 3/8x 1/4	N.R	A 3/32 SQ 1/20	A 3/32 SQ B 1/20	A 3/8x3/16 B 1/4x1/8	N.R
	30"-36"	N.R	A 1/2x1/4	N.R	A 1/8 SQ B 1/16	A 1/8 SQ B 1/16	A 1/2x1/4 B 3/8x3/32	N.R
	36"-48"	N.R	N.R	N.R	A 3/16 SQ B 1/16	A 3/16 SQ B 1/16	A 1/2 x 1/4 B 3/8x3/16	N.R
	48"-60"	N.R	N.R	N.R	A 1/4 B 1/16	A 1/4 B 3/32	A 1/2x1/4 B 1/2x1/4	N.R
C/L COMBAT 	UP TO 30"	A 1/2x3/8 B 1x3/8	A 1/2x1/8	N.R	A 3/8x3/32 B 1/16	A 1/8 SQ B 1/16	A 1/2x3/16 B 3/8x1/8	N.R
	30"-36"	N.R	A 1/2x3/16	N.R	A 3/8x3/32 B 1/16	A 3/16 SQ B 1/16	A 1/2x 1/4 B 1/2x3/16	N.R
	36"-44"	N.R	N.R	N.R	A 1/2x1/8 B 1/16	A 1/4 SQ B 1/16	A 1/2x 1/4 B 1/2x 1/4	N.R
	44"-50"	N.R	N.R	N.R	A 1/2x3/16 B 1/16	A 1/4 SQ B 1/16	A 5/8x3/8 B 1/2x1/4	N.R

FUSELAGE

NOTES:
N.R-NOT RECOMMENDED
N.S-NOT SUITABLE
H-HARDWOOD
P-PLY

		TISSUE BOX	DIAMOND	SHEET BOX	SHEET BOX	TRIANGL'R	TUBE
RUBBER	SMALL	A 1/16×3/32	A 1/8×1/16	N.R	N.S	N.S	A 1/20
	MEDIUM	A 3/32 SQ	A 3/32 SQ	A 1/16 B 1/16	N.R	N.S	A 1/16
	LARGE	A 1/8 SQ	A 1/8 SQ	A 1/16 B 3/32	A 1/32 B 3/32 SQ	N.S	A 1/16
	WAKEFIELD	A 1/8 SQ OR H	N.R	A 1/16 B 1/8	A 1/16 B 1/8 SQ	N.R	A 1/16 OR DURAL
GLIDER	SMALL	A 3/32 SQ	A 3/32 SQ	N.R	A 1/20 B 1/16 SQ	N.S	A 1/16
	MEDIUM	A 1/8 SQ	A 1/8 SQ	A 1/20 B 3/32	A 1/16 B 1/8 SQ	A 1/16	A 1/16
	LARGE	A 3/16 SQ	A 3/16 SQ	A 1/16 B 1/8	A 1/16 B 3/16 SQ	A 3/32	N.R
	A-2	N.R	N.R	A 1/16 B 1/8	A 1/16 B 1/8 SQ	A 3/32	A ·5MM. P
F/F SPORTS	SMALL	A 1/8 SQ	A 1/8 SQ	A 1/16 B 1/8	A 1/16 B 3/32 SQ	N.S	N.R
	MEDIUM	A 3/16 SQ	A 3/16 SQ	A 1/16 B 1/8	A 1/16 B 1/8 SQ	N.S	N.R
	LARGE	A 1/4 SQ	A 1/4 SQ	A 1/16 B 3/16	A 1/16 B 3/16 SQ	N.S	N.R
F/F DURATION	SMALL	A 1/8 SQ	A 1/8 SQ	A 1/16 B 3/32	A 1/16 B 1/8 SQ	A 1/16	N.R
	MEDIUM	A 3/16 SQ	A 3/16 SQ	A 3/32 B 1/8	A 3/32 B 1/8 SQ	A 3/32	N.R
	LARGE	A 1/4 SQ	N.R	A 3/32 B 3/16	A 3/32 B 3/16 SQ	A 1/8	N.R
RADIO CONTROL	SMALL	A 3/16 SQ	N.R	A 3/32 B 1/8	A 1/16 B 1/8 SQ	N.R	N.S
	MEDIUM	A 1/4 SQ	N.R	A 3/32 B 3/16	A 3/32 B 3/16 SQ	N.R	N.S
	LARGE	A 1/4 SQ	N.R	A 3/32 B 1/4	A 3/32 B 3/16 SQ	N.R	N.S
C/L STUNT	SMALL	A 1/8 SQ	N.R	A 1/16 B 3/32	A 1/16 B 1/8 SQ	N.S	N.S
	MEDIUM	N.R	N.R	A 3/32 B 1/8	A 3/32 B 3/16 SQ	N.S	N.S
	LARGE	N.R	N.R	A 1/8 B 3/16	A 1/8 B 3/16 SQ	N.S	N.S
C/L COMBAT	SMALL	N.R	N.R	A 1/16 B 1/8	A 1/16 B 1/8 SQ	N.R	N.S
	MEDIUM	N.R	N.R	A 3/32 B 3/16	A 3/32 B 3/16 SQ	N.R	N.S
	LARGE	N.R	N.R	A 1/8 B 1/4	A 1/8 B 3/16 SQ	N.S	N.S
C/L SPORTS	SMALL	A 1/8 SQ	A 1/8 SQ	A 1/16 B 3/32	A 1/16 B 1/8 SQ	N.R	N.S
	MEDIUM	A 3/16 SQ	A 3/16 SQ	A 3/32 B 1/8	A 3/32 B 1/8 SQ	N.S	N.S
	LARGE	A 1/4 SQ	A 1/4 SQ	A 1/8 B 3/16	A 1/8 B 3/16 SQ	N.S	N.S

		VERT. CRUTCH	HOR. CRUTCH	FAIRED BOX	STREAMLINE	STREAMLINE	MONOCOQUE	PROFILE	HOLLOW LOG
RUBBER	SMALL	N.S	N.S	A 1/16 SQ B 1/16 SQ	A 1/16 SQ B 1/20	N.R	N.R	N.S	N.S
	MEDIUM	N.S	N.S	A 1/16 SQ B 3/32 SQ	A 1/16 SQ B 1/16	A 1/16 SQ B LAMN.	N.R	N.S	N.S
	LARGE	N.S	N.S	A 1/16 SQ B 1/8 SQ	A 1/16 SQ B 3/32	A 1/16 SQ B LAMN.	A 1/16 B LAMN.	N.S	N.S
	WAKEFIELD	N.S	N.S	A 1/16 SQ B 1/8 SQ	N.R	A 3/32 SQ B 1/16 SQ H	A 1/16 B LAMN.	N.S	N.R
GLIDER	SMALL	A 1/2×1/8 B 1/16	A 1/2×1/8 B 1/16	A 1/16 SQ B 3/32 SQ	A 1/16 SQ B 1/16	A 1/16 SQ B LAMN.	A 1/16 B 1/16	A 1/8-3/16 B 1/16 P	N.S
	MEDIUM	A 1/2×3/16 B 3/32	A 1/2×3/16 B 3/32	A 1/16 SQ B 3/32 SQ	A 1/16 SQ B 3/32	A 1/16 SQ B LAMN	A 1/16 B 3/32	A 3/16 B 1/8	FOR POD
	LARGE	A 1/2×1/4 B 1/8	A 1/2×1/4 B 1/8	A 3/32 SQ B 1/8 SQ	A 3/32 SQ B 1/8	A 3/32 SQ B LAMN	A 1/16 B 1/8	N.S	FOR POD
	A-2	A 1/2×3/16 B 1/8	A 1/2×3/16 B 1/8	A 3/32 SQ B 3/16 SQ	N.R	N.R	A 1/16 B 1/8	N.S	N.R
F/F SPORTS	SMALL	N.S	A 1/2×3/16 B 3/32	A 3/32 SQ B 1/8 SQ	A 1/16 SQ B 3/32	A 1/16 B LAMN.	N.R	A 3/16 B 1/16 P	N.R
	MEDIUM	N.S	A 1/2×3/16 B 1/8	A 1/8 SQ B 3/16-1/8 SQ	A 3/32 SQ B 1/8 SQ	A 3/32 SQ B LAMN	A 1/16 B 1/8	A 3/16 B 3/32 P	N.R
	LARGE	N.S	A 1/2×1/4 B 3/16	A 1/8 SQ B 3/16 SQ	A 1/8 SQ B 3/16	A 1/8 SQ B LAMN	A 3/32 B 3/16	N.R	N.R
F/F DURATION	SMALL	A 3/8×3/16 B 1/16	N.R	N.R	N.R	N.R	N.R	A 1/4 B 1/16 P	N.S
	MEDIUM	A 1/2×1/4 B 1/16	N.R	N.R	N.R	N.R	N.R	N.R	N.S
	LARGE	A 1/2×1/4 B 3/32	N.R	N.R	N.R	N.R	N.R	N.R	N.S
RADIO CONTROL	SMALL	N.S	N.R	A 3/32 SQ B 3/16 SQ	N.R	N.R	N.R	N.S	N.R
	MEDIUM	N.S	A 1/2×1/4 B 3/16	A 1/8 SQ B 3/16 SQ	N.R	N.R	N.R	N.S	N.R
	LARGE	N.S	A 1/2×1/4 B 1/4	A 1/8 SQ B 1/4 SQ	N.R	N.R	N.R	N.S	N.R
C/L STUNT	SMALL	A 1/2×1/8 B 1/16	N.R	N.R	A 1/16 SQ B 3/32	N.R	N.R	A 1/4 B 1/16 P	O.K
	MEDIUM	N.R	A 1/2×3/16 B 1/8	N.R	A 3/32 SQ B 1/8	N.R	A 1/16 B 1/8	A 3/8 B 3/32 P	O.K
	LARGE	N.R	A 1/2×1/4 B 3/16	N.R	A 1/8 SQ B 3/16	N.R	A 3/32 B 3/16	N.R	O.K
C/L COMBAT	SMALL	A 1/2×1/4 B 1/16	N.R	N.R	N.R	N.R	N.R	A 1/4 B 1/16 P	O.K
	MEDIUM	A 1/2×3/16 B 3/32	N.R	N.R	N.R	N.R	N.R	A 3/8 B 3/32 P	O.K
	LARGE	A 1/2×1/4 B 1/8	N.R	N.R	N.R	N.R	N.R	A 1/2 B 1/8 P	O.K
C/L SPORTS	SMALL	A 1/2×1/8 B 1/16	N.R	A 3/32 SQ B 3/32 SQ	N.R	A 3/32 SQ B LAMN	A 1/16 B 1/8	A 1/4 B 1/16 P	O.K
	MEDIUM	A 1/2×3/16 B 3/32	N.R	A 1/8 SQ B 1/8 SQ	N.R	A 3/32 SQ B LAMN.	A 3/32 B 3/16	A 3/8 B 3/32 P	O.K
	LARGE	A 1/2×1/4 B 1/8	N.R	A 1/8 SQ B 3/16 SQ	N.R	A 1/8 SQ B LAMN	A 3/32 B 3/16	A 1/2 B 1/8 P	O.K

CHAPTER 10

COVERING AND FINISHING

THE starting-point for any good covering job is a "clean" framework. That is, all joints, etc., in balsa frames should be smoothly blended, spacers flush with longerons, no blobs of surplus cement standing up clear of the outline, and so on. All balsa surfaces, etc., should also be smoothed by sanding with "flour" glasspaper. Sanding should never be attempted too vigorously on balsa frames, however, for it is all too easy to sand away too much wood, cut notches in spars or even break relatively fragile components like ribs.

Tissue covering may be stuck to the frames with tissue paste or tissue cement, or with dope. In the former case the paste or tissue cement is applied directly to the framework (preferably with a short stiff-bristled brush) and the tissue panels laid in place. Using dope, the whole frame is given a coat of thick dope and allowed to dry. The tissue is then laid in place and dope-thinners are brushed through the tissue lying over the doped frames. This is a much more tedious method of covering and requires patience and no little skill to produce consistent adhesion. It does, however, produce a neater job. Paste (or tissue cement) adhesive is normally recommended.

Stages in covering a typical box fuselage are shown in Fig. 66. Four tissue panels are required, one for each of the sides, top and bottom, each cut at least 1 in. oversize all round. One surface is then covered at a time. Start by pasting the longerons at the middle of the fuselage. Then lay the tissue panel in place, pull reasonably taut and smooth down on to the pasted longerons. Proceed to paste a further length of longeron, top and bottom, for a further two or three bays, pulling and smoothing the tissue in place. Work first to the front; then start from the middle again and work to the rear. Surplus tissue overlapping the edges can then be trimmed off

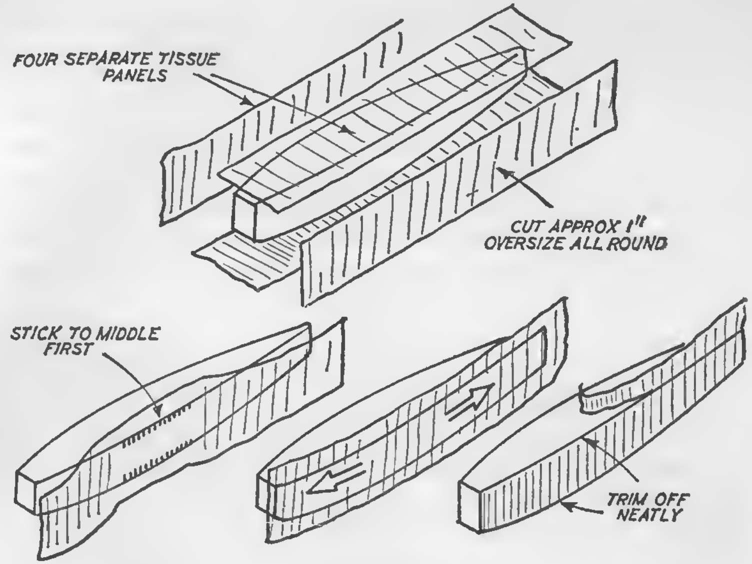


FIG. 66

flush with a razor blade. Only a new razor blade will be sharp enough to make a neat job of trimming, and it should be rinsed occasionally in water to remove paste which will tend to adhere to it.

Having completed covering of one side, the three remaining panels can then be covered in turn, in exactly the same manner. The main aim is to get the tissue applied smoothly and evenly without wrinkles, and firmly stuck down around the edges. Covering should not be stuck to intervening spacers, etc., only the outline. Also it is not necessary to pull the tissue covering absolutely taut. It is far more important to get the covering applied without wrinkles.

Covering wings is a little more tricky, but exactly the same principles apply. Separate pieces of tissue are required for the top and bottom surface of each wing panel (it is impossible to cover neatly with one piece wrapped around the leading edge), and a separate piece is needed for each panel bounded by a dihedral break (it is impossible to carry covering over a dihedral joint).

Paste is applied to the leading and trailing edges only, starting at the centre of the panel. Then work towards the tip and centre, 3 or 4 in. at a time, just as in covering a fuselage side. Alternatively, attach the tissue first to one end of the panel across a rib, then pull taut and stick down to the other end. Now work from the centre in each direction, sticking the tissue to the leading and trailing edge. Again be sure to pull out all wrinkles and aim for even tension rather than overall tautness. Trim off surplus tissue at the edges with a razor blade before

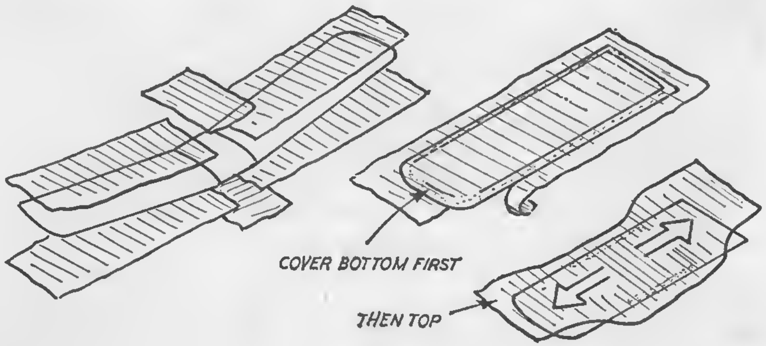


Fig. 67

starting to cover the other side of the panel. Bottom wing panels, being flat, are easiest to cover. Upper surfaces, where the tissue has to be pulled out evenly over curved ribs, are a little more difficult; but always cover each bottom panel with the appropriate top panel rather than dealing with the bottom panels first and then with the top panels.

Covering the tips may present a special problem since it may be impossible to pull out wrinkles in the top panel. In that case, terminate the top covering by pasting it on to the last rib and cut a separate piece of tissue to cover the tip. Working with these smaller pieces you should be able to produce a wrinkle-free covering. In all cases covering is pasted down to panel edges only, not to individual ribs and spars as well.

Wings with undercambered ribs need special treatment for covering the bottom surfaces. Here the covering must be attached to each individual rib and tissue paste is not suitable

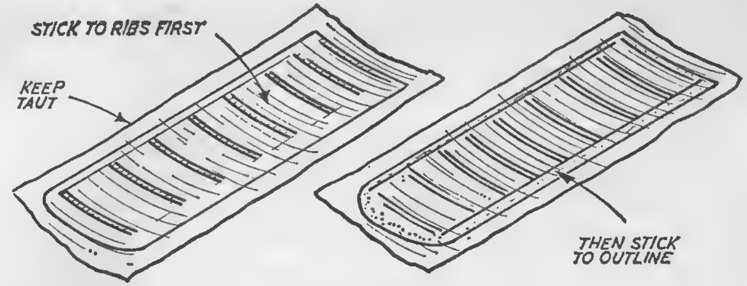


Fig. 68

for such a job. Tissue cement or thick dope must be used. Covering procedure is then to attach the covering to two or three ribs in the centre of the wing panel first, then to work along the length of the wing sticking to each rib in turn and pulling out taut (Fig. 68). Having achieved this, apply paste to the leading and trailing edges and tips and complete securing the covering to the outlines.

Tailplanes are covered in exactly the same manner as wings, except that dihedral breaks and undercambered ribs are seldom encountered (Fig. 69). Hence one panel of tissue can be used for covering the bottom surface and another panel for covering the top surface—with special treatment for the top tips, if necessary. Covering built-up fins is simpler still, using a single piece of tissue for each side and pasting down to the outline only.

Tissue-covering can then be tautened by spraying or painting

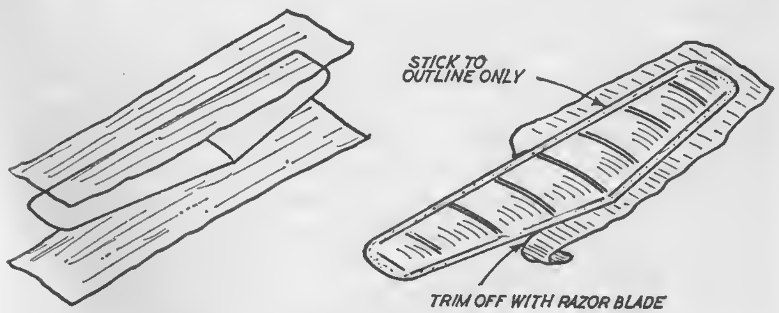


Fig. 69

with water. Spraying is best since a brush can readily tear wet tissue (especially Japanese tissue or lightweight tissue). If a brush has to be used, choose a very soft mop brush and apply very light strokes only.

On drying out the tissue will tauten appreciably, resulting in a smooth, tight covering job if (i) the tissue panels have not been applied too slackly in the first place; and (ii) the covering has been applied without wrinkles. Wrinkles are the usual fault, for bad wrinkles left in the initial covering, as applied, will never pull out; smaller wrinkles may. A good appearance to the finished, tautened covering, therefore, depends on "wrinkle-free" application in the first place.

Tautening may also introduce another problem—warping of the framework. This applies only to wings and tail units, never to fuselages. After wings and tailplanes have dried off to a "damp dry" state, therefore, they should be laid on a flat surface and weighted down so that during final tautening they cannot be pulled out of shape. This is particularly important in the case of lightweight structures—is essential, in fact, if warping is to be eliminated.

Tautened covering adds appreciably to the strength and rigidity of the framework. The covering itself, however, is relatively weak and is not suitable for normal handling. It therefore requires *doping* to provide additional strength and a reasonable degree of moisture resistance. The standard material for this is clear model dope, which itself will normally have certain tautening powers; thus any slackening of the covering under the wetting action of the dope is more than taken up again by its own tautening powers.

To avoid excessive tautening, with a further danger of warping as well as tending to make tissue-covering brittle, clear dope should be mixed with an equal proportion of thinners. At least two coats should be applied on wings and tailplanes allowing time to dry between each, and up to four coats on fuselages. More coats may be necessary to fill porous open-weave tissues or on larger models employing a heavier tissue covering. Several thin coats are better than one or two coats of thick dope, but too many coats of dope will only add unnecessary weight and make the tissue covering more brittle. Coloured

dopes should not be used, except on the larger and heavier sports-type models where weight is not so important. It is better to provide colour by using coloured tissue, even on flying-scale models.

Since clear dopes tauten on drying, the same precautions must be observed as when water-spraying tissue. As soon as the dope has dried to the extent that the surface is no longer tacky, pin or weight down wings and tailplanes on a flat surface and leave at least overnight. If this is not done, bad warps may be produced as the dope dries. It is possible to remove these warps by gently heating the surface affected (e.g. holding in front of a fire) and then twisting it true and holding in this position until the covering has cooled. There is always the distinct likelihood, however, that warps removed in this way will show up again later, and it is better if warps can be avoided entirely by taking the necessary precautions at the covering and finishing stages.

With silk or nylon covering, the basic technique is somewhat similar, although the material may be rather more difficult to get to stick down smoothly. Such materials are most easily applied in a damp state—i.e. the panel of covering is soaked in water, wrung out, and then applied whilst still damp. It is also necessary to apply such materials *quite taut* since they cannot be water-shrunk after the covering is completed, and final tautening must be done with dope. Thus considerably more skill is involved in pulling a silk or nylon panel in place tautly over the frame, and without any wrinkles appearing. It may also be expedient, or necessary, to use pins to help hold the material in place as covering proceeds.

Nylon (or silk) covering must be doped initially with full-strength clear dope. Ordinary model dope will not have enough tautening power and may even introduce slackness in what was reasonably tight original covering. Apply one, two, or three coats of full-strength dope, as necessary, to produce a good taut covering. Any further dope coatings to seal can then be thinned down, if necessary, to save adding too much weight.

Again coloured covering is best introduced by using coloured material, although this can be improved on by using a mixture of clear and thin colour dope (the same colour as the material)

for final coats. Solid colours should be restricted to trim, unless model weight is not all that important.

Conventional model dopes are reasonably resistant to diesel fuels, but are attacked and softened by glow-motor fuels. Power models, particularly those with glow engines, therefore require an additional coating of "fuel proofer." This is basically a clear varnish-type finish, resistant to fuels, which is applied as a final finish over a normal doping scheme. One overall coat of fuel-proofer is normally all that is required in this respect. Butyrate dopes, on the other hand, are fuel-resistant and can be used throughout without final fuel-proofing. The two types should not be mixed, however, so use either normal dopes throughout (followed by a coat of fuel-proofer) or butyrate dopes throughout.

The covering of sheet balsa surfaces requires a slightly different technique from that previously described for frames. The covering material (tissue, silk, or nylon) should be stuck down all over the sheet and not just to the edges. If not, the covering will invariably wrinkle. Dope is the best adhesive here for tissue covering, and gives the neatest job at the least weight, but either dope or paste can be used equally well with silk or nylon covering over sheet balsa. Finishing then follows similar lines to that already described, except that there is no point in trying to water-tighten all-over tissue covering applied to sheet balsa unless there are some "dry spots" showing because of lack of adhesion in certain areas.

In the case of control-line models, particularly sports type and speed models, weight is not particularly important and more attention can be devoted to getting a first-class finish, using coloured dopes. With solid balsa surfaces the most important part is complete filling of the wood grain, using repeated coats of dope or special grain fillers and sanding down perfectly smooth between each coat, using nothing coarser than 300 grade "wet or dry" paper for the final stages. Similar treatment may also be advisable on sheet balsa surfaces on larger free-flight models which are to be tissue- or nylon-covered, to reduce any grain roughness.

Final finishing of control-line models then follows a similar procedure to that used for automobile work. Having

TABLE XVI. GUIDE TO APPLICATION OF COVERING MATERIALS

	Fuselage	Wings	Tail
Gliders			
up to 30 in. span	Jap. or l.w. tissue	Jap. or l.w. tissue	Jap. or l.w. tissue
30–40 in. span	H.w. tissue	M.w. tissue	L.w. tissue
44–60 in. span	W.s. tissue	H.w. tissue	M.w. tissue
over 60 in. span	W.s. tissue or nylon	W.s. tissue or nylon	H.w. tissue or nylon
Rubber-powered Models			
up to 36 in. span	Jap. or l.w. tissue	Jap. or l.w. tissue	Jap. or l.w. tissue
36–48 in. span	M.w. tissue	Jap. or m.w. tissue	Jap. or l.w. tissue
48–60 in. span	W.s. tissue	M.w. tissue	M.w. tissue
Power Models			
Up to 24 in. span	M.w. tissue	L.w. tissue	L.w. tissue
24–36 in. span	H.w. tissue	M.w. tissue	M.w. tissue
36–48 in. span	W.s. tissue or nylon	W.s. tissue or nylon	M.w. tissue
48–60 in. span	Nylon	W.s. tissue or nylon	M.w. tissue or nylon
over 60 in. span	Nylon	Nylon	Nylon

Note: l.w.=lightweight; m.w.=medium-weight; h.w.=heavyweight; w.s.=wet strengthened.

satisfactorily filled the grain and obtained a glass-smooth, non-porous surface on which to work, surface imperfections remaining are filled with stopper and rubbed flat, followed by an undercoat or base coats, as necessary, again flatting between each coat. Finishing coats are then applied, with or without intermediate flatting, and perhaps finally buffed and polished after allowing ample time for the finish to dry hard. Application of the various coats by spray is more or less essential in order to obtain a true "professional" finish.

Spray application is also to be preferred for the doping of any type of model since it produces a smoother, more consistent appearance than brush painting, even with clear dopes. However, brush painting is usually considered quite satisfactory for the bulk of free-flight models.

CHAPTER 11

TRIMMING AND FLYING

THE *rigging* of a model for flight is largely a matter of ensuring that the wings and tailplane are set at their correct incidences or rigging angles, with the balance point of the model at a suitable place. Also involved in rigging is accurate alignment of

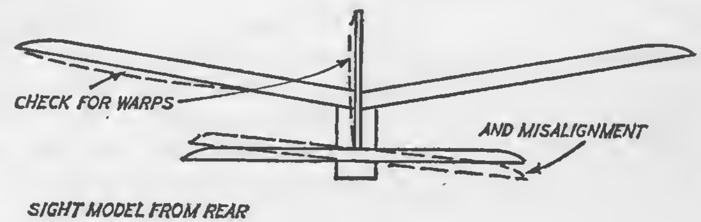


FIG. 70

the wings and tail relative to the fuselage, the fin aligned true and square, all surfaces being free from warps, etc. These are largely constructional features which need checking out before attempting a first flight with a new model.

Accuracy of alignment is usually done by eye, judging whether or not the assembled model *looks* true. In particular, warps will readily show up if the model is sighted from the rear, looking directly towards the trailing edge of the wing or tailplane (Fig. 70). Warps, or any tendency for the tailplane or fin to be out of square will usually show up clearly. These are basic rigging faults which need correcting.

To check whether the wings and tail are square to the fuselage, and parallel to each other, the simple measuring technique shown in Fig. 71 can be used. If accurately aligned, measurement *A1* should equal *A2*; and measurement *B1* should equal *B2*.

The balance point of the model is almost invariably referred

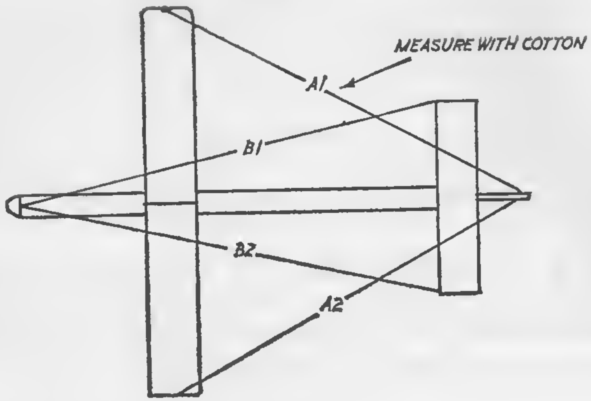


Fig. 71

to its distance back from the leading edge of the wing, that is, the model should balance level if supported under the wings at this point. The balance point, or centre of gravity as it is sometimes called, may or may not be marked on the plan. Its position is dependent on the layout of the model and also on

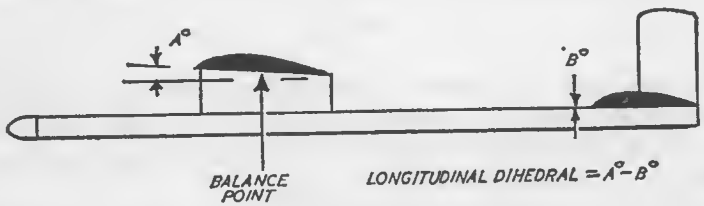


Fig. 72

the longitudinal dihedral between the wing and tailplane incidences (Fig. 72). The latter is difficult to judge or measure, but is usually fixed by the shape of the fuselage and wing mount (where applicable). The smaller the longitudinal dihedral (i.e. the smaller the difference between the rigging angles of the wings and tailplane), the farther aft the corresponding balance point. It is not vital to know exactly where the balance point is, or the exact value of the longitudinal dihedral, since both may be adjusted in *trimming* to arrive at a suitable balance of forces for stable flight.

The first flights of any new model—and all trimming flights—

should always be conducted in calm weather, preferably dead calm with no wind at all. If there is a light wind, then launching must always be done dead into the wind. It is also useless to attempt trimming in "calm" areas on windy days, such as in the lee of a building, etc. The air in such a region is far from calm, and serious damage to the model is likely to result from the upsetting effect of turbulent air causing it to crash.

Gliders are the simplest type of free-flight model to trim

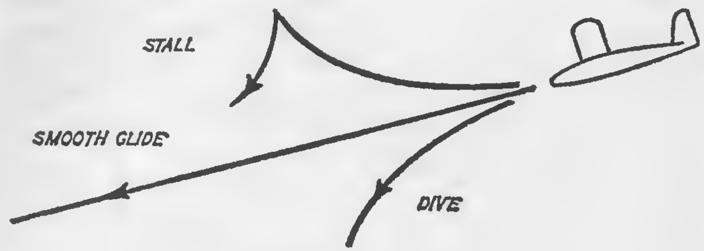


Fig. 73

since they have to be balanced for only one set of conditions—gliding flight where the "power" is provided by gravity and the model moves forwards and downwards at a gliding angle determined by its aerodynamic layout and its trim. Glide angle is not affected by *weight* of model, although the heavier the model the faster it will fly, so its time of descent from a given height will be shorter.

Hand-launching can be used to establish a rough initial trim, launching the model from shoulder height and aiming at a point on the ground about 20 to 30 ft. in front. The knack of successful hand-launching is to release the model at the correct flying attitude and speed—not nose-up or nose-down, and not too fast or too slow. Hand-launching is only good for rough trimming, but it can show whether a model is badly out of trim or not; then necessary adjustments can be made before proceeding to high-start launches.

Assuming that a glider has stable proportions to start with, its initial trim, as rigged, may give it a stable glide, a stalling flight, or diving flight (Fig. 73). If it stalls, then this over-elevated condition may be corrected by altering the *trim* by

either (i) adding more weight to the nose (equivalent to moving the balance point farther forward), (ii) shifting the wing position backwards (which has exactly the same effect as (i); (iii) reducing the rigging angle of the wing; or (iv) increasing the rigging angle of the tailplane. Both (iii) and (iv) have the

TABLE XVII.
TYPICAL RIGGING DETAILS FOR FREE-FLIGHT MODELS

Model Type	Wing Position	Balance Point (% Chord)	Wing Incidence (Degrees)	Tail Incidence (Degrees)
Gliders				
Cabin	High wing	35–40	3	0
Contest	High wing	50–66	3 to 2	0 to $+\frac{1}{2}$
Rubber Sports	High wing	35–40	3 to $3\frac{1}{2}$	0 to -1
	Shoulder wing	35–40	$3\frac{1}{2}$	0 to -1
Rubber Duration	Shoulder wing	35–40	$3\frac{1}{2}$	0
	High wing	40–50	3	0
Power Sports	Pylon wing	60–75	3	$+1$
	High wing	35–40	$3\frac{1}{2}$	0
	Shoulder wing	30–35	3	0 to -1
	Low wing	30–35	3	0
Power Duration	Pylon	66–75	2 to $2\frac{1}{2}$	$+\frac{1}{2}$ to $+1$

Note: Having established the balance of the model at the nominal or design position, trimming is most usually carried out by adjusting the tailplane incidence by packing under the leading or trailing edge.

effect of reducing the longitudinal dihedral angle, which is the same thing as applying an under-elevating trim effect to counter a balance point which was too far aft to start with. However, reducing the longitudinal dihedral angle reduces the *stability*, so methods (i) or (ii) are safer trim techniques. If the wing position is fixed by the fuselage shape, only (i) can apply; this is the usual method of trimming gliders.

Having achieved a stable glide trim another interesting fact now emerges. Gliding flight does not correspond to one par-

ticular trim. The angle of glide may be quite flat, or at the other extreme so steep that the model is really diving rather than gliding. In other words, there are degrees of trim, corresponding to different glide angles. If we start with stalling flight and add a little nose-weight at a time the glide will progressively become *flatter* until eventually a point is reached when further weight will start to steepen the glide again. Add more weight still and the model will be diving. All the time with these trim changes the flying speed of the model will be increasing.

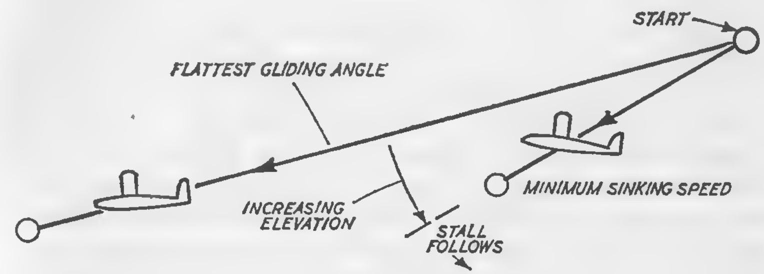


Fig. 74

Conversely, if we started with a model which was under-elevated and diving rather than gliding, reducing the nose weight to move the balance point farther aft, or increasing the longitudinal dihedral angle, would correct this condition. The glide would progressively become flatter, then start to *steepen* again, and shortly afterwards, with further over-elevating trim adjustment, the model would start to stall. This time, with small changes in trim, the flying speed of the model will be *decreasing* each time.

The two *limits* of trim which are of interest are the trim for *flattest glide* and the trim for *minimum flying speed* (Fig. 74). With the former trim the model will fly farthest from a given height. With the trim for minimum flying speed, without actually stalling, the model will have a steeper angle of glide but it will descend more slowly because it is flying at minimum speed. Thus it will give the longest duration of flight launched from a given height. It is thus called the trim for *minimum sinking speed.*

In practice, this trim is quite easy to find. The trim is adjusted, a little at a time, until the model just begins to stall. A little extra nose-weight is then added to bring the trim just below the stall, and this will correspond very closely to the minimum sinking speed for the glide. This, in fact, is the basis of "duration" trim on all free-flight models as far as the glide is concerned. It does not necessarily apply to sports-type models, however, where a flatter glide, corresponding more nearly to the trim for flattest glide may be preferred. This is because the slightly greater degree of under-elevation may be beneficial to prevent the model actually stalling in gusty air.

Glide trim can only be observed correctly when the model is gliding from an appreciable height, e.g. after tow-launching in the case of a glider. Adjustments are then made, a little at a time, and re-checked by a further "high-start" flight. It is impossible to adjust the glide trim of any model properly by hand-launching near the ground. Change in directional trim will also affect the glide trim. Thus any adjustment to make a model turn more sharply will produce a corresponding *under*-elevating effect; and conversely straightening out a turn will produce an over-elevating effect. One method of curing a tendency to stall on the glide, in fact, is to make the model describe a slightly tighter turn. This must never be overdone, however, since too tight a turn will readily finish up as a spiral dive into the ground. The under-elevating effect of a sharp turn is as powerful as that!

In the case of power models, the correct trim technique is first to establish the required glide trim and *then* to adjust the power trim. At the same time, however, the overall trim has to be fairly near the mark to start with to get the model to fly at all. Thus initial hand launched glides can be attempted to establish a reasonably "safe" glide trim, preferably carried out over long grass to cushion the model from heavy landings should it be badly out of trim to start with. The next step is then to get the model up to a sufficient height under power for the true glide to be observed and final glide trimming attempted, as required.

In the case of a rubber model this is fairly straightforward. The motor is wound up to about one-third turns only. If this

does not give enough height for a reasonable glide, try half turns, or even more. If the model shows the slightest signs of stalling under power, add a piece of packing between the top of the noseblock and the front former to give some downthrust (Fig. 75).

Work on the glide trim through a series of half-turns flights until satisfied. The power trim can now be dealt with. Basically, this involves packing the noseblock downwards slightly (downthrust) to correct any stalling tendency under power; and to

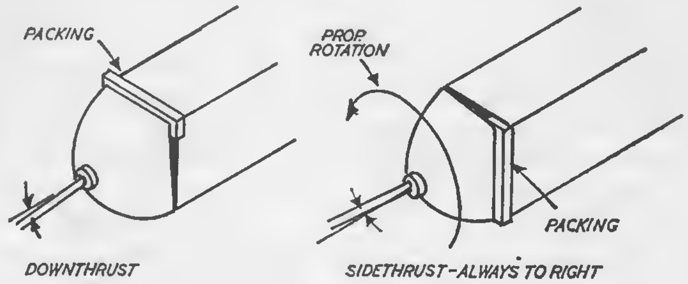


FIG. 75

the *right* (sidethrust) to counteract torque and make the model circle to the right on the climb (this being the safest and most efficient power-on trim with a propeller revolving in the conventional direction).

Neither amount of packing should be overdone, and adding side-thrust increases the effectiveness of down-thrust. If overdone, the model will go into a spiral dive to the right instead of climbing. Side-thrust should be limited to a maximum of 3 degrees (equivalent, usually, to not more than 1/32 in. packing on a small model or 1/16 in. on the largest size of rubber model). More, or less, down-thrust may be required. It is *safest* to use little or no side-thrust and do all the final trimming on down-thrust; but most efficient to use the amount of side-thrust which gives the required right-hand circle on the climb allied to the *minimum* amount of down-thrust to prevent any tendency to stall.

In making side-thrust and down-thrust adjustments, the number of turns applied to the motor is progressively increased

each flight. Trim is not complete until the model has been flown on *full turns* and the corresponding side-thrust/down-thrust adjustment established. This may also change if the motor size is altered, but otherwise can be regarded as permanent. All packings used for trim can then be cemented permanently in place—this applying also to any packing used under the tailplane (or wings) in establishing the glide trim.

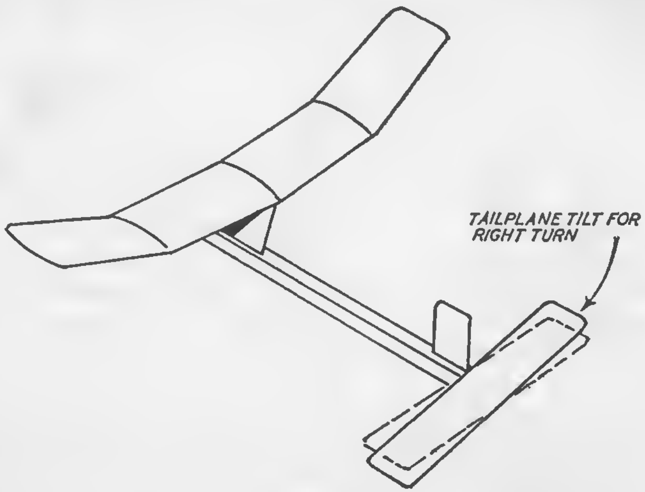


Fig. 76

With a power model the technique is essentially the same—first trimming out the glide and then concentrating on power-on trim via side-thrust and down-thrust. The main difficulty here is in getting a "reduced power" climb for the final glide adjustments. Motors do not "throttle down" easily, although some can be adjusted to run at reduced power. A timer should also be used (or a graduated fuel tank) to restrict the motor run to a matter of 5 to 10 seconds. Failing any other satisfactory method of "throttling" the motor, merely fit the propeller on back to front and adjust the engine for normal running. This will considerably reduce the thrust.

Any adjustment for *turn* must be approached very carefully with both rubber and power models. What appears a comparatively gentle turn in gliding flight can wind the model into

a spiral dive under power, particularly if this turn is given by offsetting the fin or a rudder tab. Turn adjustments of this type should be reduced to an absolute minimum. In fact, it is usually best to produce turn trim by some other means, especially on high-powered models. Devices used include trailing "drag" flaps on one wing, automatic timers for kicking a rudder over for glide turn after holding it straight during the power flight, and tailplane "tilt."

The latter is quite effective and consists of packing the tailplane up so that it is tilted relative to the wings (Fig. 76). This will induce a tendency to turn the model in the direction of the higher tailplane tip and is far less drastic in action than any rudder tab or similar control. Its use is, however, largely confined to the trimming of contest models. With sports-type free-flight models it is always better to trim for more or less straight flight or open circles on the glide as this is least likely to show up spiral-diving tendencies under power, unless the wings or tailplane are badly warped.

The high-performance "duration" model—glider, rubber, or power—normally needs some method of controlling the flight duration, otherwise the model may readily fly out of sight under thermal conditions and be lost. (All free-flight models should carry a label with the name and address of the owner, in any case, so that the finder can get in touch with the owner if the model does fly away.)

Such a device is called a *dethermalizer*, the simplest and most efficient type being the tip-tailplane (Fig. 77). The mounting of the tailplane is so arranged that one band holds it in place on its mount whilst another smaller band holds the rear end

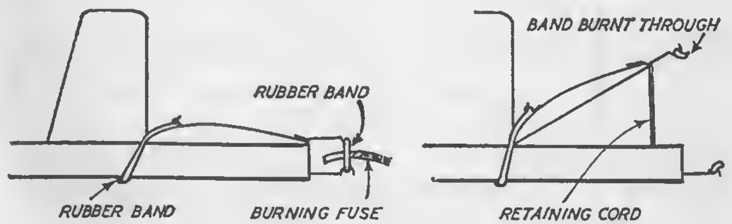


Fig. 77

TABLE XVIII.
TRIMMING CHART FOR FREE-FLIGHT MODELS

Fault	Causes	Remedy
Model noses up, then dives.	Over-elevation	Add weight to the nose, which is usually the simplest cure. If this is not readily possible, insert packing under the *leading edge* of the tail-plane or *trailing edge* of the wing. If the wing position is adjustable, move the wing back.
Model dives instead of gliding properly.	Under-elevated	Move the wing forward, if adjustable. Otherwise, add packing under the *trailing edge* of the tailplane or *leading edge* of the wing.
Model turns violently to one side.	(i) Too much rudder tab offset	(i) Reduce the amount of adjustment. If the model seems very sensitive, use tailplane tilt for turn trim.
	(ii) Warps	(ii) Check wing, tail, and fin for warps. Correct, if necessary, by heating in front of an electric fire and twisting straight.
	(iii) Incorrect alignment	(iii) Check that wing and tail are square with fuselage and each other; also that the fin is truly vertical and not angled to one side.
Model stalls under power.	Over-elevated	If glide trim is correct, add downthrust to cure power-on stall.
Model turns to one side and dives in, under power.	(i) Excessive turn trim	(i) Probably too much rudder tab offset, so reduce.
	(ii) Warps	(ii) Correct as above. Warps will show up more under power trim than on the glide.
	(iii) Too much sidethrust	(iii) Only a *little* sidethrust can be used on a model without danger of it pulling the model into a spiral dive.
	(iv) Too much downthrust used with sidethrust	(iv) If sidethrust is used, *less* downthrust is required.
Model does not climb properly.	(i) Lack of power	(i) If flight is slow, but steady, almost certainly more power is needed.
	(ii) Wrong propeller	(ii) Check that you are using the recommended propeller for the engine.
Model loops under power.	(i) Excessive power	(i) Engine is too powerful for the size of model. It may be controllable with downthrust and sidethrust.
	(ii) Incorrect power—on trim	(ii) Add downthrust for straight climb; or downthrust and sidethrust for spiral climb.
Model will not take off properly.	(i) Lack of power	(i) Needs a smoother surface to take off from.
	(ii) Wheels binding	(ii) Check that wheels are free-running and true.
	(iii) Undercarriage badly positioned	(iii) Try bending the undercarriage back slightly.
Motor cuts too soon. (Power models only)	(i) Wrong adjustment	(i) Needle valve adjusted for too lean a mixture.
	(ii) Poor tank position	(ii) Move tank to a more favourable position which does not "starve" the engine in climbing attitude.

securely down. A fuse is slipped through this rear band and lit just before launching the model. The fuse burns at a consistent rate (usually about an inch per minute) and so its action is "timed" by the length of fuse used. When it burns down to the rubber band it breaks the band, allowing the forward band to pull the tailplane up to an exaggerated angle (about 35 degrees). As soon as this happens the model will descend almost vertically and at a fair speed, sufficient to bring it down from any height through thermals, but not so high that it is damaged on landing.

There are many other types of dethermalizers, some operated by fuse and others by mechanical timers. The fuse-operated tip tail dethermalizer is, however, the simplest and probably the most effective type, and certainly the most popular. It is suitable for all types and sizes of contest models.

CHAPTER 12

ENGINES

THERE are two basic types of miniature internal combustion engines—diesels and glow motors. The diesel is a compression-ignition engine which is entirely self-contained and requires only "diesel" fuel to operate. The glow motor has a special type of plug (a glow plug) which has to be connected to a battery for starting, after which the battery can be disconnected and the plug will remain hot enough to ignite the fuel on each revolution of the engine. The fuel used in this case is an alcohol mixture (methanol plus castor oil or synthetic lubricating oil).

Both types have their advantages and disadvantages. Glow motors are usually lighter and faster revving, and also somewhat easier to start in the very small sizes. Diesels generally develop more power for the same size of engine, but have distinct limitations in the very small, or very large sizes. Thus glow motors are generally to be preferred in "baby" sizes up to about 0·5 c.c. or slightly greater; and in engine sizes above 3·5 c.c. The higher speed of the glow motor is also preferred for "racing" or certain types of contest models, using special fuels. The fact that the glow motor is lighter and vibrates less than a diesel when running also makes it a preferred choice for radio control models. A further advantage in this latter application is that the glow motor is more readily adaptable to multi-speed control than a diesel via a throttle.

There is also another type of engine which has a miniature spark plug and coil ignition and runs on a petrol/oil mixture in a similar manner to a two-stroke moped or scooter engine, etc. This was, in fact, the original type of model aircraft engine, although very few examples are made today. This is because both the diesel and glow motor show considerable advantages over spark-ignition. Both types, for example, eliminate the need for a conventional ignition circuit and the weight of such

components, and both types also develop far more power for a given size than a spark-ignition motor. The glow motor, in fact, can be regarded as a simplified and much improved type of spark-ignition motor. The diesel is a quite distinct type, developed independently.

Both the diesel and the glow engine appeared shortly after World War II and within a period of a few years had completely replaced the spark-ignition motor as a model aircraft power unit. Britain and Continental Europe concentrated on the

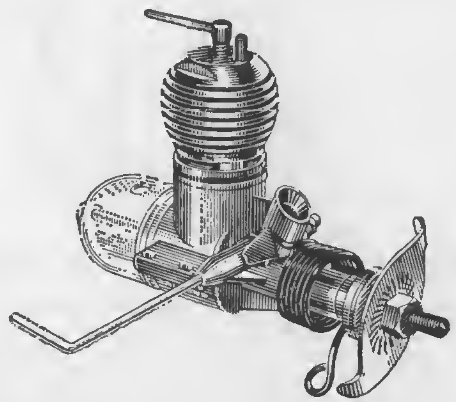


FIG. 78. The baby size (0.5 c.c. capacity) diesel makes a light, compact power unit for small models, but can be a little tricky to start.

diesel and the United States on the glow motor, largely to the exclusion of the other type in each case. Only within the last few years has the glow motor become a popular type in this country, and then mainly in the smaller sizes up to 0·8 c.c. capacity, and in larger sizes for radio-control models and large control-line models. As far as production is concerned, British manufacturers still concentrate on diesels, and American manufacturers exclusively on glow motors. The bulk of the glow motors used in Europe, in fact, are imported from the United States. The only country which currently has a large production of both types is Japan.

The fact that diesels are essentially European in origin and glow motors essentially American accounts for the fact that diesel sizes are quoted in c.c. (cubic centimetres) capacity; and

glow-motor sizes in cu. in. (cubic inches) capacity. There are also certain "standard" sizes, established largely by competition classes or popular requirements. In the case of diesels these embrace 0·5 c.c. (now largely obsolete and replaced by glow motors in this size range), 0·8 c.c., 1 c.c., 1·5 c.c., 2·5 c.c. and

TABLE XIX. STANDARD ENGINE SIZES

Glow Motors (cu. inches)	·049	·09	·15	·19	·29	·35	·49	·60
C.C. Equivalent	0·8	1·5	2·5	3·2	5	5·8	8	10

Diesels c.c.	0·5	0·8	1·0	1·5	2·5	3·5
Cu. in. Equivalent	·03	·049	·06	·09	·15	·21

TABLE XX. EQUIVALENT CAPACITIES

C.C.	1	2	3	4	5	6	7	8	9	10
Cu. in.	0·061	0·122	0·183	0·244	0·305	0·366	0·427	0·488	0·549	0·610

Cu. in.	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
C.C.	1·64	3·28	4·92	6·55	8·19	9·83	11·47	13·11	14·75	16·39

3·5 c.c. In the case of glow motors the popular basic sizes are ·049, ·09, ·19 and ·29—all referring to the capacity in cu. in. Additional sizes which have appeared, are "baby" sizes under ·049, such as ·02 and even ·01; the ·15 as matching the International contest class size of 2·5 c.c.; the ·35 as being more powerful than the ·29 for radio-control models and control-line stunt or combat; and even larger sizes for radio-control flying, such as the ·49 up to ·60 (approximately 10 c.c.). Table XIX gives a comparison of these different standard sizes. Table XX can be used to convert c.c. directly into cu. in. or cu. in. into c.c. One does not

normally speak of a glow engine size in terms of its c.c. equivalent, however, always in cu. in. The figure is also quoted directly as a size—e.g. ·19 and not 0·19 cubic inches. A diesel engine size, however, is normally spoken of as so many c.c.s.

To a large extent diesel and glow motors are interchangeable, as far as a particular model application is concerned. However, it does not follow that the "equivalent size" of engine is the same. Thus a free-flight sports model designed, say, for a 0·8 c.c. diesel *might* be underpowered if fitted with an equivalent

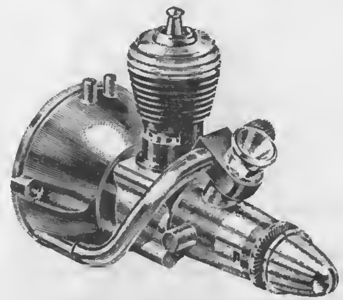


Fig. 79. The glow motor is better suited for very small sizes and is made down to 0·2 c.c. capacity. A battery is needed for starting.

size (·049) glow motor. Also certain sizes or types of models may be specifically designed around a particular type of motor. Thus the small power model designed around a ·02 glow motor might be quite unsuited to powering by an 0·5 c.c. diesel since the latter will be both too powerful and too heavy. To clarify this question of possible interchangeability, Table XXI has been drawn up as a general guide.

In the case of contest models, of course, the normal choice is an engine of the maximum size permitted under the contest rules, when the choice of engine is influenced by the *performance* of individual engines available rather than type. For sport-flying choice is usually dictated by personal preference, unless the size or type of model specifically favours a glow engine. Modellers who have experience of one type also tend to stick to it. Thus the British modellers who have used diesels and grown thoroughly familiar with their characteristics generally regard them as easier to start and handle than glow

TABLE XXI.
APPROXIMATE "EQUIVALENT" ENGINE SIZES

Diesel	Sports Type Glow Motor	Racing Glow Motor
0·5 c.c.	·049	—
0·8 c.c.	—	·049
1 c.c.	·09	—
1·5 c.c.	—	·09
2·5 c.c.	·19	·15
3·5 c.c.	·23 to ·29	·19
(5 c.c.)[1]	·29	·29
(6 c.c.)[1]	·35	·35
(10 c.c.)[1]	·60	·49

[1] Diesels are not made in these sizes.

motors. The average American modeller will have exactly the opposite view. This is purely a matter of familiarity, but it does also serve to illustrate that there is a considerable difference in the general handling characteristics of the two types.

Most new engines require a certain amount of running-in to wear off initial stiffness. This is particularly true in the case of diesels, which are usually assembled with closer clearances than glow motors. Running-in also provides an opportunity to get

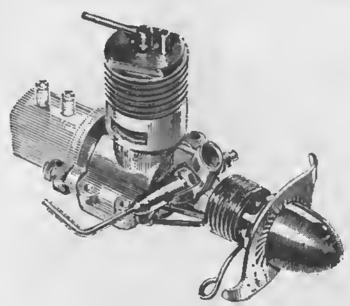


Fig. 80. The 1 c.c. or 1·5 c.c. diesel is about the most popular size for sports models (free-flight and control-line), and probably the easiest of all engines to handle. Spring starters may be fitted, but are not usual on diesels.

familiar with the starting technique and response to adjustments of controls on a particular engine and for this purpose the engine should be mounted on a bench stand or similar rig and *not* in the model.

Manufacturers' instructions are usually specific as regards starting and should be followed exactly. In the case of diesels, there are two controls—a screw on the top of the cylinder which adjusts the compression ratio and a needle valve which controls the flow of fuel entering the simple "mixing chamber"

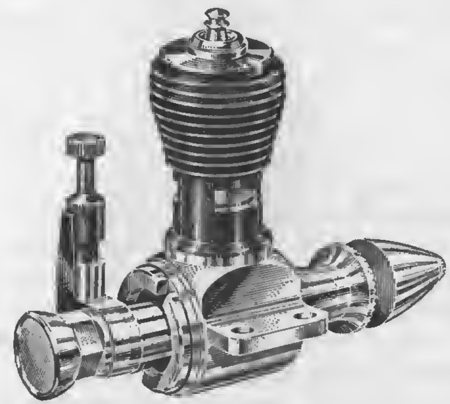


Fig. 81. This "049" (0·8 c.c.) glow motor features an induction tube at the rear of the crankcase and a reed valve, specially suitably for high-speed running. For the same size, glow motors must run much faster than diesels to deliver comparable power.

which takes the place of the carburettor on a larger i.c. engine. The "mixing chamber" merely comprises a tube through which air is sucked by rotation of the engine, with fuel fed into the throat of the tube via a small hole in a spray-bar crossing the throat. The needle valve merely controls the amount of fuel which can be sucked out of the spray-bar hole at a time.

To fire, both the amount of mixture and the compression setting must be more or less right. It is thus necessary to approach starting and control adjustment methodically. A basic technique is to open the needle valve rather more than the normal running adjustment (about two to three turns is typical) and to *prime* a cold engine by squirting a few drops of

fuel directly into the cylinder through the exhaust. Mixture control can then be ignored for the moment, and we can concentrate purely on compression adjustment. Compression needs to be increased until the engine fires and starts to run, but never increased so much that the engine becomes stiff to turn over. If this occurs, back off the compression before proceeding. To attempt to force the engine over against excess compression or a hydraulic lock caused by too much fuel in the cylinder can result in permanent damage to the engine.

With excess compression the engine may start to run and then labour to a standstill. With lack of compression the engine will not fire, or perhaps only fire occasionally. Once running, the compression can be adjusted to keep it running, and the mixture control then adjusted for fastest running. Further adjustment of compression may then be called for to get smoothest running. Mis-firing indicates lack of compression. Labouring indicates too much compression. The engine should be adjusted to run on the leanest mixture (the needle valve being screwed in as far as possible without causing the engine to stop through fuel starvation) and there should be the least amount of compression necessary to eliminate "missing." Having established these adjustments, the needle valve can be opened up (unscrewed) slightly to give a slightly richer mixture, but not so much that the engine starts to slow or run roughly. This will be the best setting both for bench running and for final adjustment before launching when the engine is subsequently installed in the model. The slightly rich mixture in this latter case will compensate for the tendency for the engine to speed up in flight owing to the air loads on the propeller being reduced.

A glow engine has only one control—the needle valve—but for starting the glow plug has to be connected to a battery. Some glow plugs are designed for 1·5 volts, so must only be used with a single cell dry battery. Glow plugs designed for 2 volts should be used with a 2-volt accumulator.

For starting, the needle valve is opened up past the normal running adjustment and the engine is "choked" by turning over with the intake tube blocked by a finger, being also primed through the exhaust port. The battery should then be

connected to the glow plug using a proper clip, when the engine can be flipped over for starting. It should start immediately, or within two or three flips. If not, something is wrong—so look for the cause as continued flicking over may only make things worse.

By far the most common cause of failure to start in the case of a glow motor is a weak battery. You need a *large* size of dry cell with a 1·5-volt glow plug. Small batteries just do not have

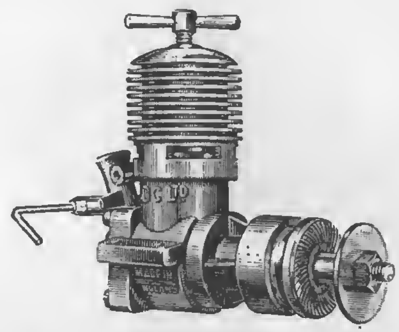


FIG. 82. For "racing" or "contest" performance diesels usually employ ball race main bearings for the crankshaft and rear rotary valve induction.

enough capacity and will be flattened in less than a minute if left continually connected. In the case of an accumulator and a 2-volt glow plug, be sure that the accumulator is fully charged to start with. *Provided* the starter battery is man enough for the job, refusal to start can then only be due to lack of fuel or too much fuel—and you can usually judge which by whether the cylinder seems to be "dry" or excessively "wet." There is, of course, also the chance that the glow-plug element may have been burnt out. This can readily be checked by removing the plug (or complete head in the case of an integral element), connecting to the battery and seeing whether it glows or not.

Running—and starting—characteristics of a glow motor will also be influenced by the fuel used. The design of a glow motor is matched to a particular fuel proportion and it will always run best on a "recommended" fuel. However, weather conditions also affect fuel performance, so what is a "recommended" and

suitable fuel for, say, southern California, is not necessarily the best for a colder climate.

A conventional "straight" glow fuel consists of methanol and castor oil in the proportions of about 7:3. Engine performance can be improved by adding dopes, such as nitromethane. Besides increasing the speed and power developed, nitromethane also improves starting and promotes smoother running. Only a little nitromethane is needed to give smoother

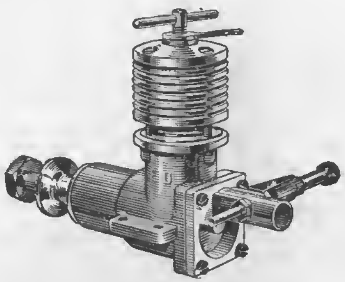


FIG. 83. Induction for this rear-rotary diesel is controlled by a port in a rotating disc inside the crankcase passing the end opening of the intake tube. The compression screw also has a separate locking device to hold its setting at high speeds which could produce vibration.

running, but performance will go on increasing with increasing nitromethane content, *provided the design of the engine is adjusted or developed around such a fuel mixture.*

Nitromethane is a very expensive additive and materially increases the overall cost of the fuel. Sports engines, therefore, are usually designed to run on "straight" glow fuel or fuels with not more than about 5 per cent nitromethane, or equivalent additive. Racing glow engines, on the other hand, may be designed to run on fuels containing 50 per cent or more of nitromethane, when the fuel cost may be ten times that of a "straight" fuel. Because of the altered proportions (mainly lowered compression ratio), such engines may not run consistently on straight fuels, although some will. Fuel proportions may also have to be adjusted to maintain top performance under different weather conditions, so the whole business becomes somewhat tricky and demands specialized knowledge

acquired only through practical experience when concentrating on racing performance.

For the general run of requirements, however, the basic rule is to use the cheapest fuel which suits the engine. That is to say, if the engine starts more easily and runs more sweetly on a lightly "doped" fuel, then it will be best to adopt that fuel as standard. There is no point, however, in going to a more heavily doped fuel (with increased expense) as there is unlikely

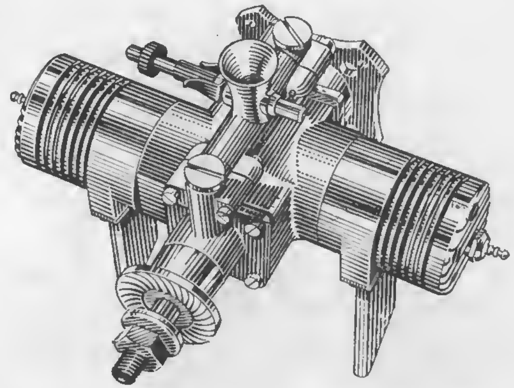


FIG. 84. This twin-cylinder 2·5 c.c. glow engine has front rotary (crankshaft) induction, with the fuel mixture drawn into the crankcase through the centre of a hollow crankshaft.

to be any marked gain in performance unless (i) the engine is designed to match "high-nitro" fuels and (ii) the engine is being used for contest work (e.g. free-flight power duration).

Diesels are far less fussy as regards fuels. Also there is no question of "hotting up" a diesel fuel with dope. There are no such additives which give a marked improvement in performance although some, such as amyl nitrite and amyl nitrate, have a *smoothing* effect on running. These are often incorporated in proportions up to about 4 per cent in standard diesel fuels for just this effect. Larger proportions do not add any greater smoothness of running and may even be harmful. Nitrobenzine is also sometimes added to diesel fuel to promote better economy of running (that is, to reduce fuel consumption), this being particularly significant in the case of team racers.

A "basic" diesel mixture comprises equal parts of ether, paraffin, and lubricating oil. The ether content is a poor fuel and is essential only to promote easy firing under compression. Small diesels tend to be a little tricky as regards "optimum" proportions of ether and may require this to be increased to 40 per cent. In other formulas the oil content may be reduced slightly to increase the amount of paraffin, but never below about 25 per cent for a new engine, or below 20 per cent on a

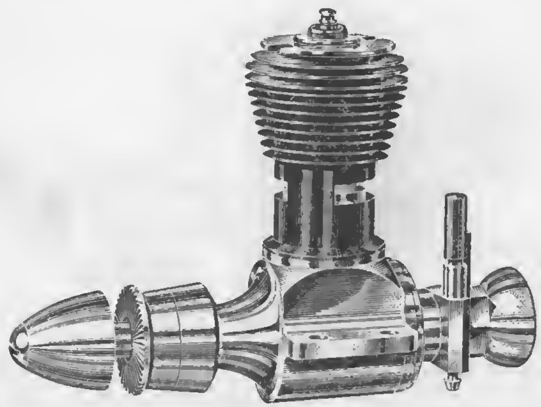


FIG. 85. Rear induction is used for this 2·5 c.c. "racing" glow motor, with mixture flow controlled by a reed valve.

well-run-in engine. Diesel-engine manufacturers usually specify a particular fuel mixture which is best suited to their particular engine but most diesels will run more or less equally well on any standard diesel mixture, although starting and running adjustments may differ from fuel to fuel. One of the most important points is always to keep diesel fuel in closed containers so that the highly volatile ether content cannot evaporate off. Stale fuel which has lost much of its original ether content may make starting very difficult, or even impossible.

It is a characteristic of all model engines that they are extremely noisy for their size and the faster and more powerful the engine the noisier it usually is. This has frequently led to complaints from nearby householders when power models are operated in built-up areas—e.g. control-line models being

flown in a park or small field. Also, of course, there are likely to be even more complaints when a noisy engine is "run-in" at home or in the garage.

Silencers can be fitted to most types and sizes of model engines and have become an obligatory fitting for contest models from January 1965. The fitting of a silencer may result in some loss of power, but this is seldom more than about 5 to 10 per cent and is negligible in the case of sports engines. As yet, however, relatively few *engine* manufacturers produce silencers specifically for their range of models and these have to be purchased as an accessory. The established modellers, too, do not take too kindly towards the fitting of silencers; but the fact remains that silenced engines do make possible the flying of models in areas where otherwise the noise would soon lead to a ban on the operation of such models.

CHAPTER 13

CONTROL-LINE MODELS

THE principle of control-line flying is shown in Fig. 86, the model being tethered by two lines attached to a handle held by the "pilot" or operator. These lines also terminate on a bell-crank securely mounted on a pivot bolt in the fuselage (or

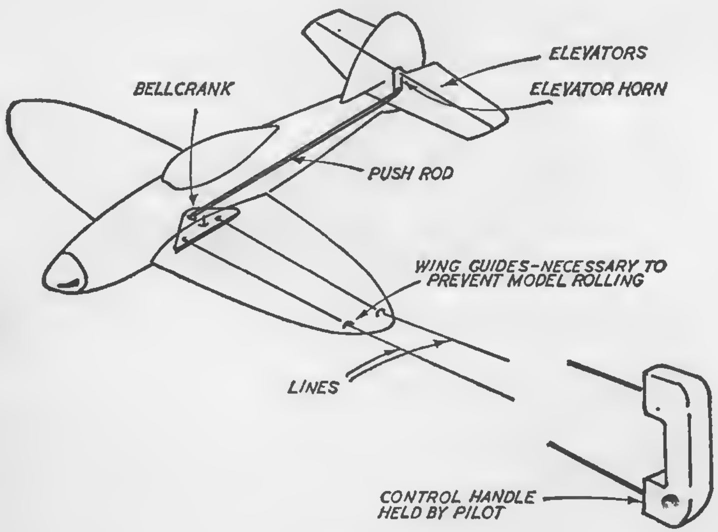


FIG. 86

sometimes to the wings in the case of small models). A stiff wire rod then connects the bell-crank to a horn attached to a hinged elevator. Thus a rocking movement of the handle will move the elevators up or down, providing control over the up-and-down motion of the model, or movement in *pitch* as it is technically called.

The basic requirement to maintain this control is that the lines remain taut, i.e. although the model is constrained to fly

in a circular path it must also pull outwards all the time. This will occur naturally provided the balance point of the model comes in front of the pivot point for the bell-crank, the farther forward the balance point the stronger the outward "pull" produced. At the same time, however, the manœuvrability of the model is reduced by such a trim. Thus whilst the typical sport or speed model may be balanced well forward, a stunt model needs to be balanced nearer to the pivot point.

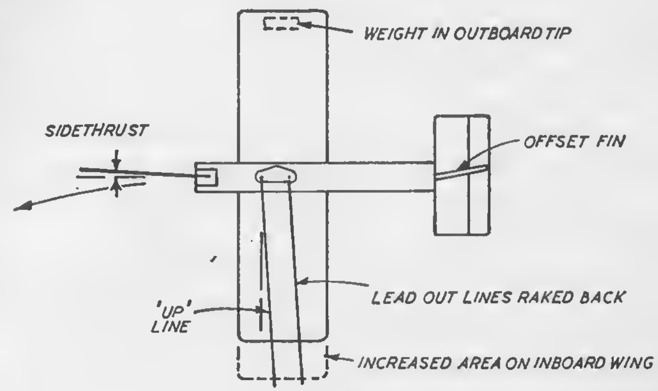


FIG. 87

In this case additional measures may have to be taken to ensure that the model maintains the lines taut during flight. There are other factors to consider, too. The stunt model is capable of wing-overs, loops, etc., where the flight path may carry the model overhead. There will thus be a tendency for the weight of the model to act against any outward "pull," which again may cause slackening of the lines and loss of control. This is particularly likely to happen if the flying speed of the model is fairly low and the line length quite long.

In order to improve manœuvrability by moving the balance point aft towards the bell-crank pivot and still maintain adequate "pull" on the lines such methods as engine offset and rudder offset may be used, both tending to pull the model outwards during flight (Fig. 87). In addition balance weight may be added to the outer tip to offset the weight of the lines (which

could cause the model to roll inwards during certain manœuvres); or the inboard wing panel may be increased in span and thus area to provide extra lifting surface for a similar effect. Line stability is also helped by angling the line backwards slightly.

Thus whilst the fact that a control-line model is flown under control means that free-flight stability problems do not arise, the more one attempts to improve the aerobatic performance of such a model the more critical the design requirements become. Apart from "line stability" or maintaining the lines taut in all flight attitudes, wing-loading also has to be kept down to a figure similar to that for free-flight models, calling for built-up wings and lighter fuselage construction than can be employed successfully on sports or speed control-line models.

Control-line model *size* is limited only by available power units. The same size of control-line model requires more power to fly than its free-flight counterpart. In practice, this simply means that control-line models are smaller for similar engine power, compared with free flight. The maximum length of line which can be used successfully is also directly dependent on the model size and engine power. Thus the smallest practical control-line models employing ".049" engine power may be suitable for a maximum line-length of about 20 ft. (although shorter lines would be preferable in windy weather), whilst the largest sizes powered by "35" glow engines may safely accommodate line-lengths of 60 to 70 ft.

Except for competition work, actual choice of line-length, within limits, is largely arbitrary. Shorter lines can be used to fly in a restricted space, but if the lines are too short the flight is less "realistic" and the "pilot" has to turn round more rapidly to follow the model. Long lines can be an embarrassment if the weather is windy since gusts may result in loss of control through blowing the model inwards—when the only recourse is to step back smartly to take up line tension again and regain control. It is always safer, therefore, to fly on shorter line-lengths rather than "maximum" lengths. Contest models are always flown on specific line-lengths, according to class and size (see Chapter 16).

The sports-type control-line model (Fig. 88) generally employs fairly straightforward, robust construction with moderate rather than high power. Manœuvrability and line stability are likely to be limited so that flying is normally restricted to shorter lengths and the flight potential limited to climbs and dives, wing-overs, and possibly loops. Many models of this type are available as ready-to-fly productions moulded in plastic. A wide range is also available in the form of prefabricated kits

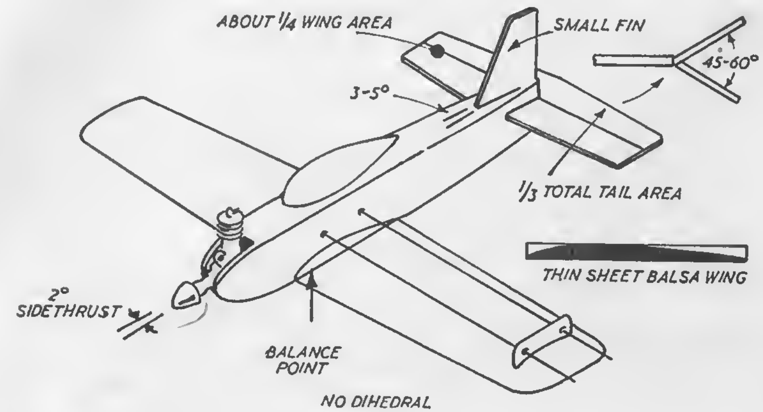


Fig. 88

which are suitable for assembly by the novice builder. They are an excellent starting point for the beginner to learn the art of *control* before advancing to a more specialized design with a greater performance potential. Unlike the case with a free-flight model, the responsibility for the safety of a control-line model lies in the hands of the pilot all the time it is in flight—thus learning to *fly* control-line is an essential requirement for success. Fortunately the basic technique is readily picked up with a little practice and the use of a robust "trainer" for this stage avoids the damage that could result to a lighter, more fragile stunt or scale model crashed by mistakes in control movement.

Having mastered the basic flying technique, the art of stunt flying must then be learnt via a proper stunt model. A useful fact here is that a small stunt model is far less likely to be

damaged by a crash than a large model, so it makes a more practical "stunt trainer." However, unless very carefully designed—and not too small—its aerobatic performance may be limited. For example, although the model may be of proper "stunt" proportions, if too heavily loaded or underpowered, it may not perform tight loops. Thus a single loop may be quite hazardous and consecutive loops out of the question. The good

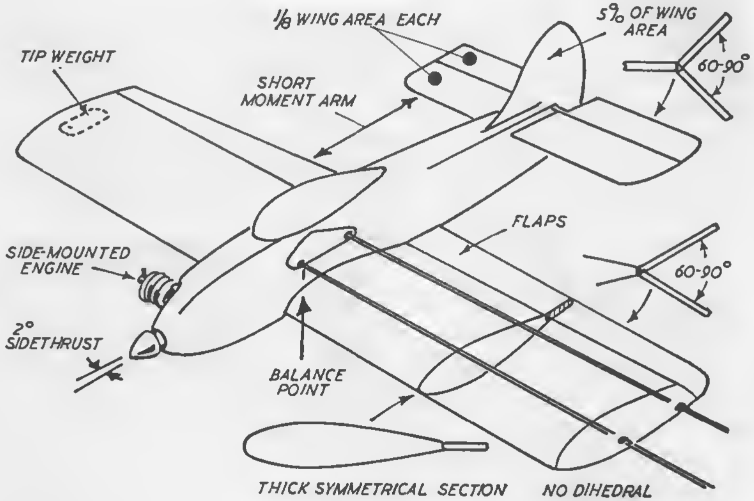


FIG. 89

stunt model, on the other hand, will perform loops with height to spare, leading to consecutive loops, figure eights, and so on. A good performance in inverted flight is also essential in a sound stunt model design calling for the use of a fairly thick symmetrical wing section (Fig. 89).

The typical stunt model tends to be larger than its sports counterpart, with considerably more wing area and an elevator movement of 30 to 45 degrees up and down. To improve manœuvrability elevator movement may also be combined with wing flap movement in the *opposite* direction (i.e. flaps lowered as elevators are moved up, and vice versa) (Fig. 90). A special "stunt" tank will also be necessary for feeding the engine with a constant supply of fuel, regardless of the flight attitude.

The main design difference between a stunt model and a sports model can be summarized as: (i) larger wing area and lighter loading; (ii) shorter tail moment arm to improve manœuvrability and particularly looping radius or "turning" radius in the looping plane; (ii) thick, symmetrical wing sections for greater wing efficiency and good performance in inverted flight; (iv) particular attention to design features maintaining line tension during manœuvres.

Although stunt models all tend to look rather similar, there are two distant lines of approach—the "minimum-size" model

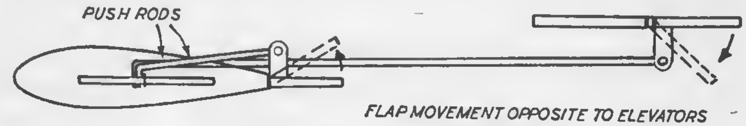


FIG. 90

with a rather higher wing loading and faster flying speed, and the large area model which has a "free-flight" loading and flies more slowly. The former is typical of the diesel-powered stunt control-line model, particularly in the smaller sizes matched to engines of up to 2·5 c.c. capacity. The larger stunt models are almost invariably powered by "29" or "35" glow motors with wing areas ranging from 400 to 600 sq. in.

The "combat" model is really another form of stunt model, except that it is intended to be flown two or more in the same circuit on identical line-lengths—each model flown by its own pilot. Each model tows a streamer and the object of combat flying is for each pilot to attempt to attack and cut the streamer(s) of his opponent(s). Whilst a thrilling and spectacular sport, the risk of collision or loss of control is considerable and crashes are frequent. As a consequence the combat model is built strongly, although the "write-off" rate still remains high! To utilize tougher and heavier structures, and still keep down to the lighter loading requirements for good manœuvrability, models of this type are usually of flying-wing layout, with the elevator hinged directly to the trailing edge (Fig. 91). Otherwise, the design requirements are basically the

same as for stunt models. The combat model can also be flown individually as a "stunt" model, if preferred.

Another popular "contest" type is the team racer. These are based on specific class sizes, governed by engine capacity (see Chapter 16) and flown on standard line-lengths. Two or more models are flown in the same circuit, the object being to cover a given distance (number of laps) in the minimum time. Pit

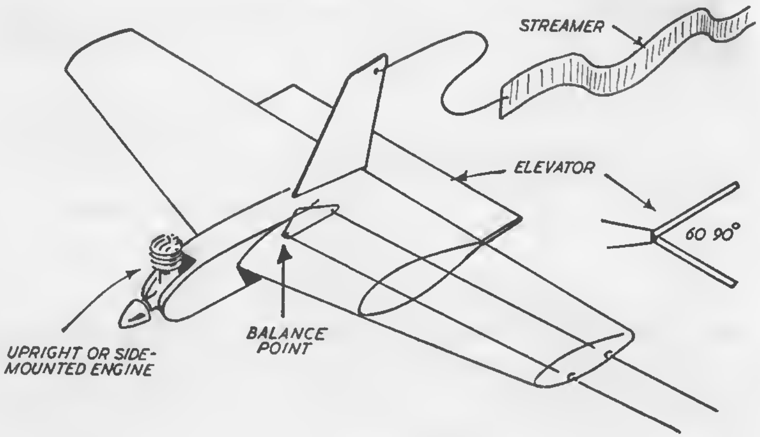


FIG. 91

stops are usually necessary for refuelling, calling on close co-operation between the pilot and "pitman" who refuels the model and restarts the engine after each stop. The models themselves are invariably of semi-scale design, with cowled in engines, although some concession to "model performance" is often seen in the use of single wheel undercarriages.

A team racer can also make an attractive "sports" model for the individual flyer who is attracted by "realism." Design proportions are such, however, that manœuvrability is restricted to climbs, dives, and wing-overs. Equally, sports control-line models although not conforming to team-race contest specifications can be used for "team racing" by individual groups of modellers.

Speed models are essentially models for the specialist and they all tend to have a similar overall appearance, like that

shown in Fig. 92. Originally there were no limiting specifications regarding model proportions and official classes were merely designed by engine size. More recently minimum areas have been specified as a requirement of the model design.

Since the overall requirement is purely maximum speed, basic requirements boil down to a streamlined model of minimum size based around a suitable engine (the most powerful available in its class!) and propeller. Relatively little control

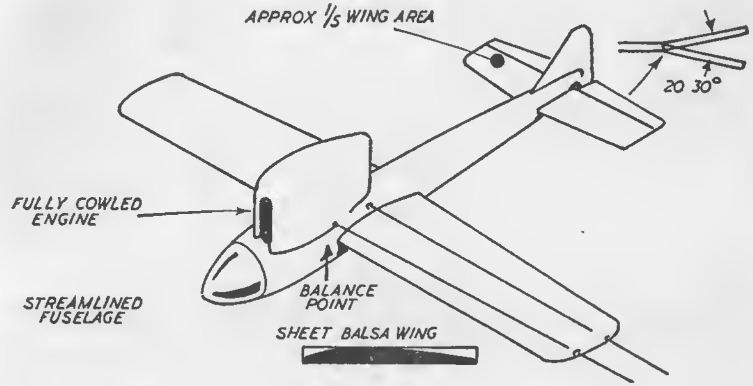


FIG. 92

is needed—only enough to be able to take off and control the model in level flight, and bring it in to a smooth belly landing. The undercarriage is invariably omitted to save drag, the model taking off from a wheeled "dolly" which it drops or leaves behind as soon as it is airborne (although speed models may also be hand-launched). Wing sections are made thin (again to reduce drag) and the whole model is often polished or burnished to a superfine finish. The greatest proportion of drag is then accounted for by the lines.

To reduce line-drag, line-diameter is kept to a minimum (limited only by strength requirements). "Monoline" control may also replace conventional two-line systems, again to save the drag of one wire. In this case control is realized by applying twist or *torsion* to the single line, this movement being translated at the model end as bell-crank movement via a screw drive. Again this is strictly for the expert modeller

TABLE XXII. TYPICAL SIZES OF SPORTS MODELS AND TRAINERS

	Engine Size				
	0·5 c.c. Diesel or ·049 Glow	0·8 c.c. Diesel	1–1·5 c.c. Diesel	2·5 c.c. Diesel	3·5 c.c. Diesel or ·29 Glow
Span	15–18 in.	20 in.	24 in.	30 in.	36 in.
Wing chord	3½ in.	4–4½ in.	5 in.	6 in.	7 in.
Wing area sq. in.	60–70	80–90	120	180	250
Propeller sizes	6×4 5×4	6×4 6×6	7×4 7×6	8×6 8×8 9×6	9×8 10×6
Line length	12–18 ft.	15–22 ft.	20–30 ft.	30–40 ft.	50–60 ft.
Lines	Thread	33 s.w.g. wire or thread	30 s.w.g. wire	30 s.w.g. wire or stranded c/l wire	Stranded c/l wire

TABLE XXIII. TYPICAL PROPELLER SIZES FOR STUNT MODELS

	Engine Size				
	1·5 c.c.	2·5 c.c.	3·5 c.c. (0·19cu.in.)	5 c.c. (0·29cu.in.)	0·35 cu. in.
Prop. diameter	8 or 7	8 or 9	9 or 10	10	10
Prop. pitch	4 or 6	4 or 6 or 4	4 or 6 or 4	5	5 or 6

TABLE XXIV. TYPICAL SIZES OF SPEED MODELS

	Engine Size				
	(0·8 c.c.) ·049 Glow	(2·5 c.c.) ·15 Glow	(3·25 c.c.) ·19 Glow	(5 c.c.) ·29 Glow	(10 c.c.) ·60 Glow
Span	11–12 in.	14 in.	15 in.	17–18 in.	20 in.
Wing area (sq. in.)	14–15	24–28	25–30	30–35	40–50
Tail area (sq. in.)	6	9–10	10	15	18
Weight (ounces)	4–5	8–10	9–10	12–14	20–24
Length	9	13	14	15	18
Lines	36 s.w.g.	33 s.w.g.	33 s.w.g.	30 s.w.g.	28 s.w.g.

since the piloting technique required is quite different and has to be re-learnt.

Ultimately the performance of the speed model depends on the engine/propeller combination, top performances normally being realized by extensively reworked and specially tuned "racing" engines. The average modeller has virtually no chance of success in competition against the speed control-line experts, many of whom (especially on the Continent) are sponsored by the engine manufacturers. Engine performance is also directly related to a suitable fuel tank installation, the flexible "bladder" tank being highly favoured since pressure feed is more reliable than conventional tanking. Even the flying of a speed model itself is highly specialized, competition requirements calling for the use of a special pivoted yoke mounted on a pylon in the centre of the flight circle, in which the pilot must rest his arm so as to avoid any possibility of assisting the performance of the model by "whipping."

Control-line models undoubtedly offer the would-be model-designer the greatest scope since stability problems are reduced to a minimum. Control-line is also by far the safest solution for flying scale models, particularly for flying for fun, and where a large amount of detail work, etc., can be incorporated without having to worry too much about added weight, or the possibility of serious damage resulting through lack of "free flight" stability. Choice of prototype is not limited to single-engined aircraft for twin-, three-, and four-engined flying scale (control-line) models are perfectly practical. Added realism can be introduced by operating retractable undercarriages, wing-flaps, bomb-dropping, etc., triggered by a third line (normally slack but pulled to trigger the operation of a secondary control). Such devices are not practical on free-flight models, except with elaborate (and expensive) radio-control systems.

CHAPTER 14

RADIO-CONTROLLED MODELS

THE remote control of free-flight models via a radio link has been developed to the stage where the radio equipment available is extremely reliable and requires no specialized knowledge of electronics either to install or to operate it. All such equipment is designed to operate within a frequency band of 26·96 to 27·28 megacycles/second, this waveband being allocated by the G.P.O. for model radio-control systems. A G.P.O. licence is required to operate any such equipment, the cost being £1 for a five-year period. A licence is obtainable on application, no technical or other qualifications being required.

The basic elements involved in any model radio-control system are a transmitter, a receiver, and an actuator. The transmitter is invariably designed to transmit a constant frequency carrier signal within the permitted frequency band and is commonly crystal-controlled to ensure a stable signal frequency (although this is not obligatory in this country). The receiver may be designed to respond directly to the carrier signal, or to a lower frequency *tone* signal superimposed on the transmitter carrier. The latter is normally the preferred system. In either case the receiver response takes the form of a change in current flowing through the receiver circuit. This in turn is used to operate a relay whose contacts then form an "on-off" switch for the actuator circuit. Alternatively, the relay may be dispensed with and the receiver current amplified to a suitable level to operate the actuator direct (relayless receiver).

The actuator is an electro-magnetic device providing the power to move a control. As far as the mechanical working of the complete system is concerned the transmitter-receiver combination merely acts as an "on-off" switch for the actuator. The same effect would be produced by using a manually-operated switch in the actuator circuit comprising simply the

battery and actuator. The radio link, however, enables "on-off" switching to be accomplished over a distance of several miles, if necessary (although the normal ground-to-ground range of typical model radio-control systems is about half a mile).

The simplest form of actuator is the *escapement*, which itself is powered by a rubber loop (Fig. 93). A radio signal received

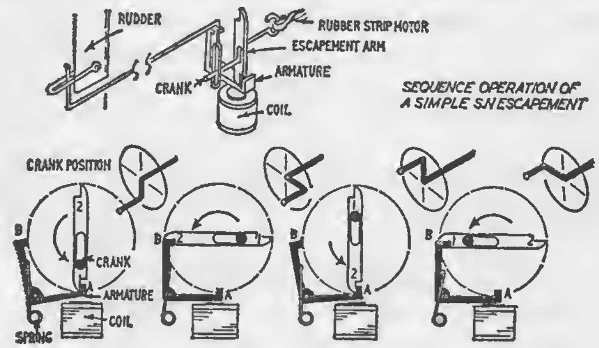


FIG. 93

by the receiver is passed on to the actuator either directly (relayless receiver) or indirectly (through closure of relay contacts) to cause current to flow through the actuator coil. This pulls in the armature, allowing the escapement to rotate a quarter of a turn under the action of the rubber motor, when it is brought up against another stop. This quarter-turn movement can be used to move a control surface via suitable linkage. On release of the radio signal the current through the coil ceases, the armature drops out and the escapement rotates a further quarter turn. At the same time the attached linkage returns the control surface to its original or "neutral" position. The next signal, producing a further quarter-turn rotation, will move the control surface in the opposite direction, returning to neutral again on release of signal. Such an actuator, therefore, provides alternate control positions *in sequence*, returning to neutral (self-neutralizing) on release of signal.

A transmitter, receiver, and actuator of this type form the basis of a simple *single-channel* system, which is a perfectly practical

method of controlling a free-flight model when the control action is linked to the *rudder*. It is possible to provide additional controls, again in sequence, from a single signal or single radio channel by designing the escapement with a greater number of "stopping" points. This, however, causes practical difficulties both in signalling correctly to the required sequence position and as regards speed in selecting a particular control position. The usual limit is a "third" position on the actuator which can be signalled at will to operate a *second* actuator, which in turn then operates a further control (usually engine speed). An alternative arrangement is to use this "third" position to hold an elevator either "up" or "down" for a change in trim.

Owing to the development of transistor circuitry which, in addition to compact sizes for the receiver, means that battery requirements are very modest, the complete installed weight of a lightweight single-channel radio-control system can be as low as 3 ounces. Thus radio control is a practical proposition for free-flight power models from about 20 in. span upwards. Whilst ideal for operating in small spaces, such tiny models are, however, suitable only for calm-air flying. For training purposes a 40–48 in. single-channel model is much better, powered by a 1 to 1·5 c.c. diesel or glow motor equivalent. This gives scope for providing both rudder and engine speed control (the latter via a second actuator coupled to an engine with throttle control), using a "compound" actuator. Engine speed control—either "fast" or "slow," selected in sequence by signalling the "third" control position on the actuator, provides a means of bringing the model down as well as controlling direction by the rudder.

The cost of a complete single-channel radio-control system can be as low as £10 where the transmitter and receiver are assembled from kits, or roughly twice this figure using finished commercial equipment. At best, however, single-channel radio only provides *partial* control and models have to be designed with about the same amount of inherent stability as free-flight sports models, although the proportions and fuselage outline shape may differ. The usual—and most successful—layout is the high-wing monoplane with semi-scale lines—Fig. 94.

Receiver, batteries, and actuator are located in the centre of the fuselage to concentrate these weights around the balance point of the model. The fuel-tank fitted is larger than normal in a free-flight model, usually containing sufficient fuel for flights of 10 or 15 minutes duration.

The main limitation with single-channel radio is lack of elevator control. Various ingenious systems have been devised whereby both rudder and elevators can be operated by a single control channel and one, known as the "Galloping

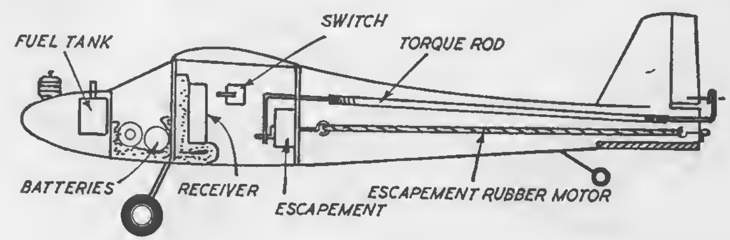


Fig. 94

Ghost" actually provides *proportional* movement of rudder or elevator. All such systems, however, have their distinct limitations. The only fully satisfactory method of extending control coverage is by utilizing *multi-channel* radio control. Unfortunately this also greatly increases the cost of the radio equipment.

The conventional multi-channel radio system operates on *tone* signalling, but instead of a single tone superimposed on the transmitter carrier separate "tone" switches on the transmitter enable a number of different tones to be signalled independently. Each tone then provides a separate channel for control signalling. The receiver, in turn, must be capable of decoding the various tones and responding by a switching action as far as the associated actuators are concerned.

There are two basic methods of "decoding" multi-channel tones. The first, and simplest, uses a *reed bank* which is something like a relay with a number of individual reeds replacing the armature. Each reed is trimmed to a specific length and resonates or vibrates when a particular tone signal is fed to the reed bank coil. The vibrating reed then closes a corresponding

actuator circuit connected to the reed contacts (Fig. 95). The reed bank simply has the same number of resonant length reeds as there are transmitter tones to be decoded. Each reed circuit completed by its contact when the reed is vibrating then either operates a relay switching the actuator, or supplies current to operate the actuator direct through a suitable amplifier circuit to boost the current (relayless receiver).

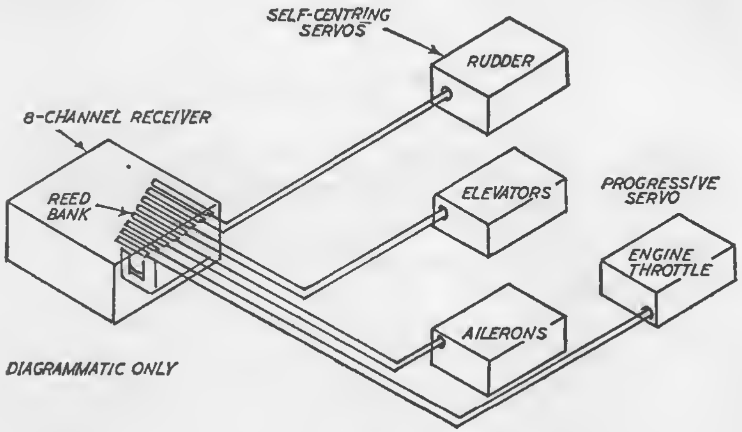


FIG. 95

The other basic method of decoding the transmitter tones is to employ electronic filters in the receiver circuit, each filter passing only one particular tone to operate its specific relay. This leads to a more complicated (and expensive) receiver, and also a heavier unit because of the additional filter components involved. It does, however, have the advantage that the individual tone frequencies can be more widely separated and thus there is less risk of interference between adjacent tones.

The actuator in the case of a multi-channel system becomes a *servo* signalled by *two* tones, each servo being associated with a particular control. The servo itself is, basically, an electric motor. Operation of one tone signals the motor to drive in one direction, and operation of the second tone signals the motor to drive in the opposite direction. Built-in switching is incorporated in the servo unit to stop the motor when it has driven

to a "full" control position, and also to provide automatic drive back to the neutral position when the tone signal is released—a self-centring multi-servo. Alternatively, the self-centring action can be eliminated so that the servo can be "inched" in either direction by appropriate tone signals—progressive multi-servo. Self-centring servos are used for the main flying controls (rudder, elevators, and ailerons); and

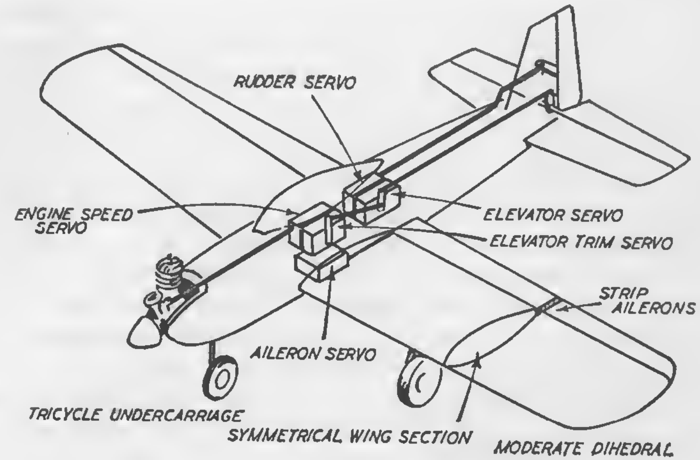


FIG. 96

progressive servos for trim controls (elevator trim, aileron or rudder trim, and engine speed) (Fig. 96).

The particular virtue of multi-channel signalling where two channels control one servo is that a particular control position is signalled *direct*, that is, there is no lag in having to switch through a sequence to repeat a control movement, as with single-channel actuators. Also, of course, given enough channels, direct control can be provided on *all* necessary control surfaces.

For *complete* control of a free-flight power model *eight* channels are required, covering rudder, elevators, ailerons, and engine speed. A further control for elevator trim is also desirable, making ten channels required in all. A model with this control complement can be flown under control all the time in a similar manner to a full-size aircraft. Provided the "pilot"

has the necessary skill, therefore, the model does not have to be stable itself. It is, in fact, a decided advantage for the model to have more or less neutral stability, when it will be that much more manœuvrable. It must not be *unstable*, however, as this could over-ride the control available to correct, e.g. if an unstable model was deliberately put into a spin it might not be possible to pull it out of the spin again by corrective action on the controls.

In the case of a radio-controlled glider, of course, *complete* control coverage can be given with only six channels (rudder, elevator, and ailerons). However, an additional two channels for elevator trim control will be a distinct advantage. At the other extreme, four channels (covering rudder and elevators) would provide *adequate* control for slope soaring, etc., provided the model had a reasonable degree of free-flight stability.

The only real limitation to increasing the number of channels with "multi" radio is one of cost. The modern relayless "multi" receiver with a ten-reed bank can be used for two to ten channels, simply by adding servos and their amplifiers. The cost, however, goes up by a matter of about £10 per servo (i.e. £10 for every additional control service added). The additional weight and bulk is seldom critical, for the individual servos can be quite small in size and weigh little more than 2 ounces each.

Typical multi-channel aircraft designs have features which would make them definitely unsuitable for free flight (without control). The low-wing layout is widely favoured, with only moderate dihedral angles and moderate, rather than exaggerated, tail-surface areas. Complete control enables them to be flown safely in high winds or other conditions which would "ground" the normal free-flight sports model; also the power used is higher than that for normal free flight. Given a reasonable design layout, in fact, much of the success of a multi-channel aircraft depends on its having enough power to perform manœuvres in the vertical plane. Full power does not have to be used all the time for, with throttle control, the engine speed can be adjusted as required. As a consequence "49" and even "60" glow motors are commonplace fitted to models of 5–6 ft. wingspan.

Anything *less* than eight channels cannot give complete control, so in such cases a different type of design is required with a certain amount of normal free-flight stability. Usually this means a high- or shoulder-wing layout, with a more generous dihedral angle on the wings. Rudder is an essential control, which would normally be allied to engine speed (with four channels) or engine speed and elevators (with six channels). With just two channels only rudder control can be used. However, this will still show distinct advantages over single-channel rudder-only control since rudder response is signalled *directly*. Multi-channel radio is, in fact, the only real answer to satisfactory radio control of aircraft. Single-channel radio retains its popularity only because it is so much cheaper.

The ultimate in multi-channel operation is achieved with *proportional* control systems. With conventional radio control all the main flying controls (rudder, elevator, or ailerons) are either full "on" (control signalled and held) or "off" (control signal released and the servo self-centring to neutral). With proportional control, movement of any control surface is directly proportional to the movement of the corresponding control stick on the transmitter, in just the same manner as the controls of a full-size aircraft follow exactly the movement of the control column. Flying a model aircraft with proportional radio control is, therefore, exactly the same as flying a full-size aircraft, except that the pilot is standing on the ground rather than sitting in the aircraft. This does present some difficulties in co-ordination but, once the technique is mastered, the control achieved is considerably smoother than that possible with conventional "multi" controls.

The main drawback is that the additional complication to the radio side, and the actuators, considerably increase the cost of such equipment. Thus whilst the cost of a complete ten-channel conventional multi installation may be £100 to £150, the cost of a comparable proportional system is at least doubled. This puts it well out of the range of the average model enthusiast.

Although the majority of modern radio-control equipment is extremely reliable, there are still snags, notably on the question of interference. The conventional receiver circuit is of the

TABLE XXV. RADIO-CONTROLLED MODEL CHARACTERISTICS

Model Type	Wing Dihedral	Radio	Controls	Remarks
High wing	8°	Single-channel	Rudder only	Typical free-flight layout
	5–6°	Single-channel	Rudder, engine, trip elevator	With compound actuator
	4°	6-channel	Rudder, engine, elevators	—
	2–3°	8- or 10-channel	Rudder, engine, elevators, ailerons	Not so suitable for aerobatics as low wing
Shoulder wing	10°	Single-channel	Rudder only	—
	8–10°	Single-channel	Rudder, engine, trip elevator	With compound actuator
	5–8°	6-channel	Rudder, engine, elevators	Good "multi" trainer
	3–5°	8- or 10-channel	Rudder, engine, elevators, ailerons	—
Low wing	12–15°	Single-channel	Rudder only	Not really suitable
	8–10°	Single-channel	Rudder, engine, trip elevator	Tricky to fly
	5–8°	6-channel	Rudder, engine, elevators	More tricky than high wing
	3–4°	8- or 10-channel	Rudder, engine, elevators, ailerons	Best aerobatic layout

super-regenerative type which is highly sensitive but not *selective*. That is to say, although tuned to a particular transmitter it will almost certainly respond to any spurious signals which might be present within the model waveband (e.g. another transmitter). A super-regen receiver may also interfere with another receiver fairly close to it. It is thus impossible to fly more than one model at a time with a super-regen receiver as any other transmitter operated within a mile or so is likely to cause interference, although not directly tuned to that receiver. This applies whether the transmitter is crystal-controlled or not. The average super-regen receiver is sufficiently non-selective and broad in tuning to pick up *any* transmitter signal over the full range of 26·96 to 27·28 mc/s.

The solution here is to employ a superhet circuit for the receiver, although again this increases the cost. The particular virtue of the superhet is that the tuning is extremely sharp and, with crystal control, it can be matched exactly to a "spot" frequency established by the transmitter crystal. Another transmitter-superhet receiver combination tuned to a different "spot" frequency within the permitted band can then be operated simultaneously without interference. In fact, as many as ten or twelve transmitter-receiver combinations may be operated simultaneously at different "spot" frequencies between 26·96 and 27·28 mc/s, although five or six is a more usual number.

The additional cost of the superhet receiver is thus justified by its freedom from interference, whether or not it is intended to operate simultaneously with another modeller. It is not completely free from interference. A "broad" (i.e. non-crystal controlled) transmitter signal could interfere with it by overlapping the spot frequency; or any other spurious signal embracing the spot frequency. It is, however, very much better than the super-regen receiver in this respect and it is also capable of responding to weaker transmitter signals because of its greater selectivity, so that its range tends to be improved with the same transmitter. In other functional respects it is similar to the super-regen receiver and is applicable to both single- and multi-channel units.

CHAPTER 15

INDOOR MODELS

MODELS suitable for flying indoors embrace a variety of different types, ranging from small rubber-powered "round-the-pole" or tethered models for small-space flying to highly specialized ultra-lightweight duration models capable of flight durations of more than half an hour and requiring the use of an airship hangar or similar large, unobstructed building for flying!

Performance with all indoor models, free-flight or tethered, is entirely dependent on length of motor run (except that chuck-gliders may be flown in large enough buildings). The i.c. engine is largely ruled out as a practical power unit for indoor models, which means that rubber is the standard motive power. Motor run is then primarily dependent on being able to use the smallest possible motor cross-section (for maximum number of turns per inch of motor length) together with the largest possible diameter propeller. In turn, this means an ultra-lightweight model. Thus the 30-minute-plus indoor duration model may have a span of some 30–36 in. With a propeller of 16 in. diameter powered by a two strand motor of 1/16 sq. in. cross-section, the complete model weighs a matter of 1/20 ounce!

To get down to such extreme lightness the construction is very fragile, involving the use of carefully selected balsa of minimum density and "sparless" wing and tailplane construction, covered with microfilm. The propeller is also normally built up as an ultra-light balsa frame, and is also microfilm-covered. Microfilm itself is formed by pouring a few drops of clear dope (suitably plasticized) on to water, where it spreads out into an extremely thin film and sets. The film is then lifted off by means of a wire hoop, applied to the framework as a covering and the edges are trimmed off with a hot wire.

Extreme patience and skill are needed both to construct and to handle models of this type, which are quite outside the scope of the average model-builder's abilities. Smaller models of this type may, however, be produced quite successfully for small-space flying with duration capabilities of a minute or more; and similar stronger and heavier free-flight models may be suitable for tissue covering with similar scope. Conventional built-up tissue-covered rubber-powered models are either too large or too heavy, and fly too fast for satisfactory indoor flying.

Basic principles of the "round-the-pole" model are shown in

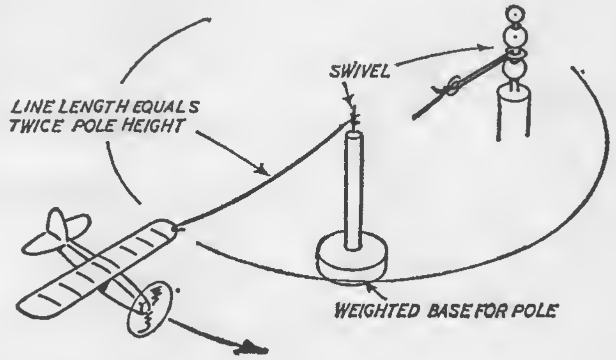


FIG. 97

Fig. 97. The model is tethered by means of a very light line to a swivel fitting on the top of a short pole and flies in circles round the pole for as long as the rubber motor develops enough thrust via the propeller. With very lightweight construction, and microfilm-covered wings and tail, rubber section may be reduced to the extent that 5–6-minute flight durations are possible on a line length of some 12 ft. and a pole height of 6 ft. Tissue-covered models require a more powerful motor because of the increased weight, but still may be capable of flights of 3 minutes' duration or more, with specialized designs and skilful construction. More robust models, flown purely for fun, may achieve flight durations for from 30 seconds to a minute or more, flying much faster and with smaller propellers. Many of these are based on the smaller rubber-powered flying-scale

kits, fitted with much larger propellers to prolong the motor run.

Round-the-pole or "RTP" flying also lends itself to "speed" models, designed expressly with powerful rubber motors and small high-revving propellers, the motor run being sufficient to cover a specified number of laps at maximum possible speed (Fig. 98). A longer "course" can be covered by "pit stoppages" for rewinding the motor, the winner being determined as the one with the least elapsed time to complete the

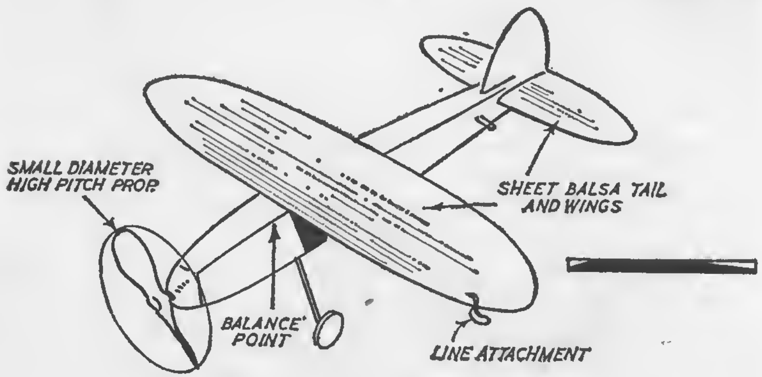


FIG. 98

whole distance (number of laps). Speed models of this type have a popular appeal for junior aeromodelling club activities during the winter months when outdoor flying is restricted by the weather. RTP duration flying, which once had a wide club and National contest appeal, is no longer particularly popular, although it is recognized as a "National" contest type.

Two "official" sizes are specified—Class A for models up to 1 ounce maximum weight, and Class B for models between 1 and 2 ounces in weight. Pole-heights are 3 ft. and 6 ft. respectively; and line-lengths 6 ft. and 12 ft., respectively. This general rule that the line-length should be twice the pole-height applies for all "duration" RTP flying, whether for fun or contest work. In the former case the line length can be selected to suit the space available, e.g. a sitting-room.

For speed RTP models pole-height is usually made shorter in proportion, the official S.M.A.E. size being a pole-height of

18 in. and a line-length of 5 ft. 6 in., with the official distance for timing purposes ten laps.

An essential requirement for satisfactory *free-flight* performance with any indoor model is a very low flying speed, which can only be achieved by employing the lightest possible structure coupled with a reasonable size of model. It is not just a question of model size. Thus a small "outdoor" rubber-powered model is not suitable for indoor flying, even in a relatively large hall, because it flies too fast and is very prone to suffer damage on striking an obstacle. The true indoor free-flight model flies literally at less than walking pace, with the large diameter propeller turning over very slowly. Attempts to make the model smaller whilst retaining a similar form of construction inevitably result in a loss of performance since certain material weights cannot be reduced in direct proportion to size. The result is a higher wing loading, and a greater flying speed.

The 12–15 in. span microfilm-covered free-flight model can, however, be trimmed to fly in small circles and give flights of a minute or more in an average-size room—flight duration normally terminating when the model strikes a wall and slides down it (the model will not weigh enough to crash!). In a larger hall similar models may produce flight durations of several minutes under conditions too restricted to operate a larger model. The small (15 in.) model may well weigh more than its larger counterpart, and thus be less tricky to construct and handle. It is an interesting field for the serious enthusiast to investigate, particularly since models of this type cost very little to build and can be "sized" to suit the flying area available. Every school, for example, will have a hall large enough to provide space for microfilm model flights of several minutes' duration, and perhaps for similar performances with very lightly-constructed tissue-covered models.

The best durations are invariably realized with a "stick" model layout, since this is by far the lightest and simplest type to construct. The fuselage consists of a light, hollow stick made by rolling thin balsa sheet into the form of a tube or "teardrop" section. This stick carries the rubber motor suspended beneath it. Tailplane and fin and lightweight structures are carried on a

separate boom attached to the stick fuselage, whilst the wing is invariably "parasol"-mounted on thin struts (Fig. 99). These struts plug into tiny tubes cemented to the top of the stick fuselage and also provide a means of adjusting the incidence of the wings to trim, if necessary.

A similar basic layout is used in all sizes of such models, the real secret of weight reduction being in the choice of balsa and

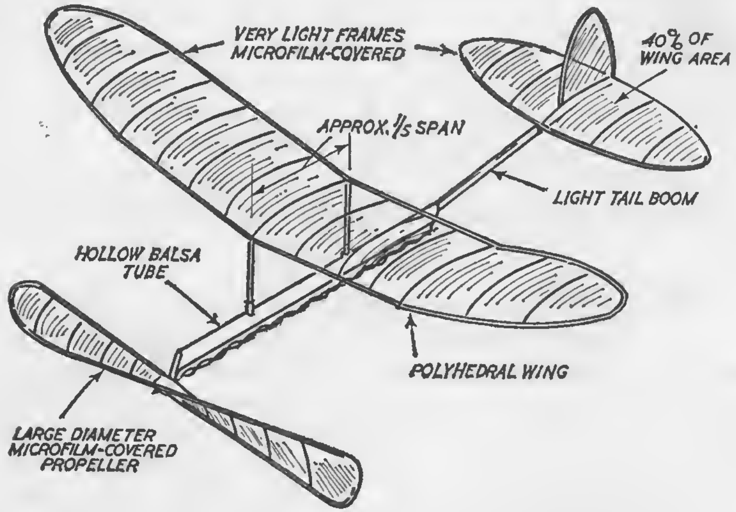


FIG. 99

the use of minimum material sizes consistent with just enough rigidity in the complete structure. In the case of larger models the wings, and often the fuselage stick too, are braced with very thin tungsten wire, involving very intricate construction and painstaking workmanship. It is virtually only possible to "build down to weight" through a whole series of models, starting with more generous wood sizes and using thinner, lighter stock as experience is gained. Attempting to duplicate a record-breaking model for a first attempt is almost certainly foredoomed to failure.

A reasonable size of indoor flying space also gives scope for trying unorthodox models, such as ornithopters and small, simple helicopters. Construction again must be kept light, but

not so light as for "duration" models since flight performance will be limited, to start with anyway. The scope offered by indoor models is, however, far more restricted and less satisfying than that provided by outdoor models, unless one finds a particular attraction in the challenge offered by the microfilm-covered "duration" model.

CHAPTER 16

CONTEST MODELS

THE International sport of model flying is run under a Sporting Code issued by the Fédération Aéronautique Internationale (F.A.I.), who are also responsible for the ratification of World Records. Annual or bi-annual World Championship events in various categories are also held under F.A.I. regulations.

National contests and national organization are handled by individual bodies in the countries concerned, usually affiliated to or part of the National Aero Club. The British authority is the Society of Model Aeronautical Engineers (S.M.A.E.), who are responsible for ratifying National Records, organizing National contests, selecting British teams, etc. The general sporting and contest activities in the country are organized by local clubs, themselves affiliated to the S.M.A.E., with their own local flying grounds. These in turn may organize flying meetings, normally called galas, which whilst not having National status as competitions attract contestants from other clubs all over the country.

A particular virtue of local club membership—apart from the good-fellowship of meeting and flying with other aeromodelling enthusiasts—is that third-party insurance coverage is provided, although this can also be negotiated by individuals who are not club members. Insurance cover of this nature is inexpensive and is thoroughly to be recommended to all model-flyers, especially anyone who operates a power model.

As regards overall definitions, a model aeroplane is defined as having a total surface area (combined area of wings and horizontal tailplane) of not more than 16·14 sq. ft., and not exceeding 11·023 pounds (5 kilograms) in weight. In the case of power models, motors should not exceed 10 c.c. capacity (0·61 cu. in.).

The various categories of model aeroplanes are as described

in Chapter 1, grouped broadly under "free-flight" and "control-line," with specific types and classes in each category. In addition a number of general rules apply to models flown in contests, with which entrants must be familiar. Such regulations are summarized in a Contest Rule Book published by the S.M.A.E.

GLIDERS

The World Championship formula for model gliders is known as the A/2 and calls for a model conforming to the following specification—

(i) Total area of wings and horizontal tail surface to be between 496 and 527 sq. in.

(ii) Minimum total weight of the model to be 14·46 ounces.

(iii) Maximum loading (i.e. weight divided by total area) to be 16·38 ounces per sq. ft.

The standard method of launching is by a tow-line not exceeding 164 ft. in length.

(Note: The odd and fractional specification figures result from the fact that world championship specifications are derived originally from metric units.)

Gliders of other size or type may, of course, be used for "open" competitions organized on a National or club basis. The A/2 merely represents a specialized contest class, and the only one recognized for World Championship events.

RUBBER MODELS

The World Championship class here is the "Wakefield" formula with the following specification—

(i) Total area of wings and horizontal tail surface to be between 263·5 and 304·5 sq. in.

(ii) Minimum total weight of model to be 8·11 ounces.

(iii) Maximum loading to be 16·38 ounces per sq. ft.

(iv) Maximum weight of rubber motor to be 1·768 ounces.

This is a "restricted" formula in the sense that the limitation to rubber weight considerably reduces the potential performance of a model which could be built within the specification

items (i) and (ii). For this reason many rubber models are built for higher performance (unrestricted rubber weight) for "open" competitions.

Power Models

For World Championship and International events the maximum size of engine is restricted to 2·5 c.c. The following restrictions then apply to the model design—

(i) Minimum total weight of model to be 10·58 ounces per c.c. of engine capacity.

(ii) Minimum loading to be 6·55 ounces per sq. ft.

(iii) Maximum loading to be 16·38 ounces per sq. ft.

(iv) Maximum duration of engine run to be 10 seconds from release of the model.

National (British) contests also admit of unrestricted power models where only the engine-run restriction above applies; and the ½A power class where engine size is restricted to a maximum of 0·85 c.c.

There is also a Pay-Load category where the model is required to carry a dummy pilot of specified dimensions and weight in an acceptable pilot's compartment in the fuselage. This again is a special "restricted" formula. For engine sizes up to 0·82 c.c. the model (less fuel and payload) must weigh at least 5 ounces; and for engines from 0·85 to 1 c.c., 6 ounces. The standard "pilot" must weigh 4 ounces, with an additional payload of 1 ounce in the case of motors up to 0·82 c.c., and 2 ounces for engines larger than 0·82 c.c.

Control Line Stunt (aerobatic)

No limitations are placed on model design or construction other than the restriction that the model must not weigh more than 6 pounds and the engine must not be larger than 10 c.c.

Lines must be of steel, and any length between 25 ft. and 70 ft. can be used, with the following minimum line diameters specified—

Engines up to	2·5 c.c.	33 s.w.g.
" "	2·5–6·0 c.c.	30 s.w.g.
" "	6–10 c.c.	26 s.w.g.

TABLE XXVI. TEAM RACER SPECIFICATIONS

	Class		
	½A	A (International)	B
Engine capacity	1·5 c.c. max.	2·5 c.c. max.	2·51–5 c.c.
Min. wing area	90 sq. in.		133 sq. in.
Min. total area (wings and tail)	—	186 sq. in.	—
Min. width of fuselage at cockpit	1·5 in.	1·97 in.	2 in.
Min. depth of fuselage at cockpit	3 in.	3·94 in.	4 in.
Min. fuselage cross section at cockpit	—	6·045 sq. in.	—
Min. wheel diameter	1 in.	1 in.	1 in.
Max. fuel tank capacity	6 c.c.	10 c.c.	30 c.c.
Max. weight	—	24·7 ounces	—
Line length (to c/l of model)	46 ft. 8 in.	52 ft. 3 in.	60 ft.
Min. line diameter	0·010 in. (33 s.w.g.)	0·0118 in.	0·0124 in. (30 s.w.g.)
No. of laps: heats	90	10	70
final	180	20	140

The complete control system must also be capable of withstanding a pull of at least ten times the weight of the model.

Scoring points are allocated for the quality of performance of a sequence of standard manœuvres.

Control-Line Team-Racers

Three classes are recognized, based on engine size and with model dimensions, etc., related accordingly. These specifications are summarized in Table XXVI. The line-length in the case of Class ½A is equivalent to 18 laps to one mile; and in Class B to 14 laps to one mile. The line-length in the case of the International Class A is equivalent to 10 laps equalling one kilometre distance covered.

Standard distances run are 5 and 10 miles in Class ½A and Class B; and 10 and 20 kilometres in the Class A. The lower distance in each case corresponds to heats and the longer distance to finals.

Control-Line Speed

One World Championship formula and five additional classes are recognized in this category. The World Championship formula is of a "restricted" type, permitting the use of one of two standard fuels only (80/20 or 75/25 methanol/castor), thus excluding diesel engines. Maximum engine size is limited to 2·5 c.c. and the model must have a minimum total area (wings and horizontal tail surfaces) of 2 sq. decimetres (31 sq. in.) per c.c. of engine displacement; and a maximum loading of 32·76 ounces per sq. ft. Radius of the flight circle is 52 ft. 2¾ in., giving 10 laps equal to one kilometre. Minimum line diameter permitted is 0·0098 in. (33 s.w.g.) in the case of two lines; or 0·0136 in. (29 s.w.g.) in the case of monoline control.

Details of the other five speed control-line classes are summarized in Table XXVII for convenience of reference. All speed flying for official timing is done with an anti-whip pylon (see Chapter 13).

TABLE XXVII. CONTROL-LINE SPEED CLASSES

	Class				
	0	1	2	3	4
Engine size	0–1·5 c.c.	1·51–2·5 c.c.	2·51–5 c.c.	5·01–10 c.c.	Jets
Max. motor weight	—	—	—	—	17·5 ounces
Max. model weight	—	—	—	—	35 ounces
Line-length	47 ft. 5¾ in.	52 ft. 2¾ in.	58 ft. 0½ in.	65 ft. 3¼ in.	65 ft. 3¼ in.
Laps per kilometre (timed distance)	11	10	9	8	8
Min. line size: Two lines	0·0076 (36 s.w.g.)	0·010 (33 s.w.g.)	0·0108 (32 s.w.g.)	0·0145 (28 s.w.g.)	0·0148 (28 s.w.g.)
Monoline	0·0108 (32 s.w.g.)	0·0137 (29 s.w.g.)	0·0148 (28 s.w.g.)	0·020 (25 s.w.g.)	0·020 (25 s.w.g.)

Control-Line Combat

There are no restrictions on model design or construction but for the purpose of S.M.A.E. (National) competition engine size is restricted to a maximum of 3·5 c.c. with line-length standardized as 50 ft. The streamer carried by the model should be 10 ft. long by 1½ in. wide, securely attached to the rear of the fuselage or fin by a 5 ft. length of strong thread. The total period of combat time is 5 minutes, with points *deducted* at the rate of 1 for every 15 seconds the model is *not* airborne during this time; add points scored at the rate of 5 for each single cut of an opponent's streamer.

INDEX

A
th wide variety
of co but, after whetting his
appetite on one ... t soon feels the urge to make
both cars and track for him:

Electric Model rs provi ould-be car builder with the expert guidance that should im (or her—there is already quite a following of women to build and run model cars that would be at least as good as anything that can be bought, and, with only moderate care and a capacity for taking pains, will be very much better. Only the simplest tools and materials are needed; very little space is required since the finished car is unlikely to be more than five inches long. Indeed, the whole "workshop" can go in a small attache-case.

Detailed instructions are given for making racing, sports, and "drag" cars, including both chassis and body; the book also covers track building, trackside scenery, speed-controlling mechanisms, timing devices, and gives a simple description of basic principles, so no one need hesitate to take these first steps to being a "World Champion" in miniature.

The author has been keenly interested in electric model cars since they first appeared in the magazine which he was editing some ten years ago. He has continued to encourage the development of this branch of modelling until today it is part of an immense industry, and he retains his interest and activity by editing *Model Cars*, a magazine solely devoted to the hobby.

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